

5301543  
P114

NASA Contractor Report

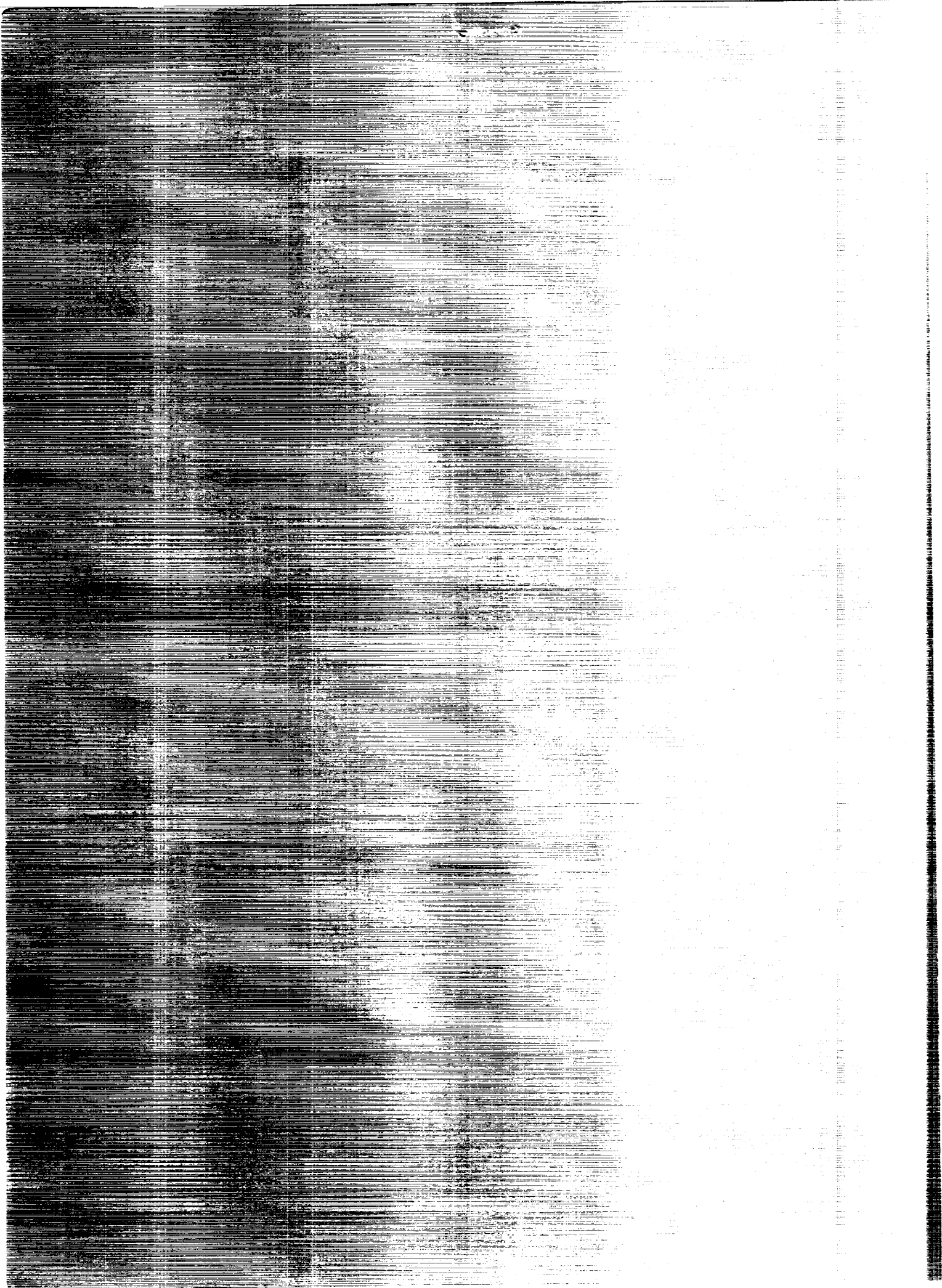
# USSR Space Life Sciences Digest

*Issue 30*

CONTRACT NASW-4292  
MAY 1991

LOCKHEED ENGINEERING AND SCIENCES CO. (LOCKHEED ENGINEERING AND SCIENCES CO.) 112 0 CSCL 06F

Unclass  
H1/51 0020070



NASA Contractor Report 3922(36)

# USSR Space Life Sciences Digest

*Issue 30*

*Edited by*

Lydia Razran Stone and Ronald Teeter  
*Lockheed Engineering & Sciences Company*  
*Washington, D.C.*

Joseph Rowe  
*Library of Congress*  
*Washington, D.C.*

Prepared for  
NASA Office of Space Science and Applications  
under Contract NASW-4292



National Aeronautics and  
Space Administration  
Office of Management  
Scientific and Technical  
Information Division

1991



## TABLE OF CONTENTS

<i>Reader Feedback Form</i>	<i>vi</i>
<i>From the Editors</i>	<i>vii</i>
<b>ADAPTATION</b>	1
Evaluation of endurance of repeated exposure to space flight factors as a function of whether readaptation is complete.	1
Resistance, Stress, Regulation.	2
<b>BIOSPHERIC RESEARCH</b>	4
Biophysical and Clinical Aspects of Heliobiology: A Collection of Scientific Papers.	4
<b>CARDIOVASCULAR AND RESPIRATORY SYSTEMS</b>	6
Bioelectrical activity in cosmonauts' hearts during long-term flights on space station Mir.	6
Regional circulation in cosmonauts on long-term space flights.	7
Study of the cardiovascular system during the second Soviet-French flight (Ekhokardiografiya Experiment).	8
Performance and functioning of the cardiorespiratory system in response to additional resistance to respiration.	9
Use of the Penaz method of continuous noninvasive blood pressure measurement to predict human status during gravity-induced blood redistribution.	10
State of the pumping function of the myocardium in monkeys after a 7-day period of hypokinesia with head-down tilt.	12
<b>ENDOCRINOLOGY</b>	13
The effect of shift work of air traffic controllers on parameters of sympathetic adrenal system activity.	13
Cyclic nucleotides in blood and urine of healthy males after long-term exposure to weightlessness and hypokinesia with head-down tilt.	14
<b>EQUIPMENT AND INSTRUMENTATION</b>	16
A photoelectric method for recording human rotational eye movements.	16
<b>GASTROINTESTINAL SYSTEM</b>	17
Comprehensive evaluation of the function of the gastrointestinal tract during space flight.	17
<b>GROUP DYNAMICS</b>	19
Personality traits of aviation specialists in small working groups with various levels of psychological compatibility.	19
<b>HABITABILITY AND ENVIRONMENTAL EFFECTS</b>	20
Microflora of the cabin of manned spacecraft and the problem of biological damage to the structural materials used in them.	20
<b>HEMATOLOGY</b>	22
The effect of a 13.5-day space flight on the blood profile and bone marrow of rats.	22
Changes in hematocrit in humans under conditions of long-term hypokinesia and space flight.	24
Use of electron paramagnetic resonance to analyze the blood plasma of mice exposed to rotational acceleration combined with ascorbic acid and GABA.	25
<b>HUMAN PERFORMANCE</b>	26
Information interaction between operator and computer during exposure to adverse environmental factors.	26
Physical and psychogenic effects of impact acceleration on operator performance in a tracking system.	27

## TABLE OF CONTENTS

<b>IMMUNOLOGY</b>	28
Phenotype properties of human lymphocytes in weightlessness and hypokinesia studied using monoclonal antibodies.	28
Production of the major mediator of immunity, Interleukin-2, and expression of IL-2-receptors by lymphocytes in cosmonauts after flights on space station Mir.	30
The human immune system in response to a 1-year period of hypokinesia and long-term space flight.	31
The natural cell-mediated cytotoxicity system in hypokinesia with head-down tilt 370 days in duration.	33
<b>LIFE SUPPORT SYSTEMS</b>	35
A substrate for long-term cultivation of plants in inhabited spacecraft.	35
Special Feature: The quails that flew in space.	37
<b>MATHEMATICAL MODELING</b>	41
Mathematical rationale for determining a sufficient number of measurements for reliable evaluation of recorded parameters in space biology and medicine.	41
<b>METABOLISM</b>	42
Lipid peroxidation: 1-year space flight and its ground-based simulation.	42
Evaluation of metabolic status in humans after exposure to real and simulated weightlessness.	44
The effect of elevated doses of ultraviolet radiation on certain metabolic parameters in humans.	46
<b>MUSCULOSKELETAL SYSTEM</b>	47
The modifying effect of weightlessness on repair processes in rats (as indicated by results of biochemical analysis of blood).	47
Reactions of human skeletal muscle fibers to a 370-day period of hypokinesia with head-down tilt combined with physical exercise.	48
Change in the ultrastructure of striated muscle and neuromuscle synapses of rats in response to a 13-day space flight.	53
Histomorphometric analysis of the bones of rats exposed to space on biosatellite COSMOS-1887.	56
<b>NEUROPHYSIOLOGY</b>	59
Higher nervous activity in primates flown on biosatellite COSMOS-2044 and in a control ground-based experiment.	59
The accommodation function of the eye in cosmonauts.	61
Pattern of vestibular reactions and sensory interaction in weightlessness.	63
The effect of certain neural mediators and neural modulators on the electrical activity of neurons of the medial vestibular nucleus.	67
The effect of space flight factors on the auditory function of cosmonauts.	68
Intersensory interaction in simulation of the effects of the space adaptation syndrome.	69
The tracking function of the eyes in weightlessness.	71
The Effects of Space Flight Factors on the Central Nervous System: Structural-Functional Aspects of the Radiomodifying Effect.	72
<b>NUTRITION</b>	76
Vitamin fortification of cosmonaut diet on long-term flights.	76
<b>PSYCHOLOGY</b>	77
Personality traits determining risk taking.	77
Mechanisms for Recognition of Unfamiliar Stimuli.	78

## TABLE OF CONTENTS

<b>RADIOBIOLOGY</b>	8 0
Radiocerebral effects of combined exposure to extreme levels of space flight factors.	8 0
The problem of radiation safety in space flight under exposure to combined effects of ionizing and non-ionizing radiation.	8 2
Radiation physics results of the Soviet-Bulgarian "Doza-B" experiment on space station Mir.	8 4
The problem of ensuring radiation safety on the manned Mars mission.	8 5
Radiobiological aspects of support of radiation safety on flight to Mars.	8 6
Effects of exposure of the eyes to elevated doses of ultraviolet radiation on the eyes and behavior of rats.	8 7
<b>SPACE BIOLOGY AND MEDICINE</b>	8 8
Review of the major medical results of the 1-year flight on space station "Mir."	8 8
Hypokinesia and Weightlessness: Clinical and Physiological Aspects.	9 6
Physiological Problems of Weightlessness	9 9
<b>KEY WORD INDEX</b>	1 0 1

## USSR Space Life Sciences Digest: Issue 30 Reader Feedback Form

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract Number rendering	Incorrect or inappropriate term	Suggested

Dr. Lydia Stone  
Lockheed Engineering and Sciences Company  
600 Maryland Ave. SW  
Suite 600, East Wing  
Washington, DC 20024



FROM THE EDITORS

Scientists acting as technical reviewers for this issue are:

Dr. Gary Coulter  
Dr. Victoria Garshnek

Dr. Ronald Dutcher  
Dr. Walter Schimmerling

Dr. Mary Anne Frey  
Dr. John Uri

Address correspondence to:

Dr. Lydia Stone  
Lockheed Engineering  
and Sciences Company  
600 Maryland Ave. SW  
Suite 600, East Wing  
Washington, DC 20024  
Phone (202) 863-5269



PAPER:

P1374(30/91) Voronkov Yul, Tizul AYa, Gornago VA, Sokolov VI.

***Evaluation of endurance of repeated exposure to space flight factors as a function of whether readaptation is complete.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 38-39.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Adaptation, Readaptation, Repeated Exposure  
Humans, Males, Age Differences; Cosmonaut Selection, Repeated Flights  
Hypokinesia With Head-Down Tilt

Abstract: One of the main goals of modern space medicine is to maintain the health and safety of cosmonauts, and also to support a high level of performance at all stages of space flight. Increased duration of flights and the need for repeated flights on reusable spacecraft such as Buran or Space Shuttle make it necessary to study the effects not only of differences in space flight duration, but also of differences in the intervals between repeated flights.

With this goal, two experiments were performed to study the effects of two 30-day periods of hypokinesia with head-down tilt ( $-8^\circ$ ) with different intervals between the first and the second exposures (10 and 30 days). The subjects were apparently healthy young men (20-25 years old) and older men (over 40) with age-related health problems.

The results of the experiments showed that when exposure to hypokinesia with head-down tilt was repeated after readaptation was complete (30-day interval), the duration and severity of the clinicophysiological symptoms during the initial period of adaptation to the second treatment were curtailed. However, a second exposure to hypokinesia, which started before readaptation was complete, i.e. 10 days after first exposure, induced more severe changes. In particular, during the later stages of the second hypokinesia period, changes in lipid and hormonal patterns and energy metabolism and hemodynamic disturbances were more serious, especially in subjects over 40.

The data obtained may be used to evaluate the duration of the recovery period (readaptation) and to define acceptable intervals between successive space flights.

## MONOGRAPH:

M172(30/91) Yakovlev GM, Novikov VS, Khavinson VKh.  
 Resistents' Stress, Regulyatsiya, Resistentnost' Stress. Regulatsiya [*Resistance, Stress, Regulation.*]

Leningrad: Nauka; 1990.

[238 pages; 16 figures; 6 diagrams; 19 tables; 498 references]

Key Words: Adaptation, Psychology, Stress, Resistance, Injury, Frostbite, Burns, Isolation, Airtight Environments, Arctic Conditions, Immunology, Immunodeficiency, Endocrinology, Thymus

Annotation: This monograph considered the principles and mechanisms of resistance under extreme ecological conditions, in physical and psychoemotional stress, during prolonged isolation in airtight quarters, and under exposure to the combined effects of adverse factors. Changes in the resistance in recovery from injury, burns, and frostbite are analyzed. The pathogenic mechanisms underlying development of immunodeficiencies, their prevention and correction are discussed. The efficacy of using peptide regulators of thymus function to treat primary and secondary immunodeficiency conditions, acute and chronic purulent-inflammatory and infectious diseases, the disruption of regenerative processes, and thymus hypofunction are covered. A rationale is presented for principles of bioregulation therapy, which increases the efficacy of prevention and treatment of a number of diseases.

## CONTENTS

Foreword	(5)
List of Abbreviations	(6)
Introduction	(7)
Chapter 1. The Physiology of Extreme Effects	(10)
Principles and mechanisms of adaptation	(10)
Functional systems of resistance	(17)
Adaptive responses of defensive mechanisms	(30)
Chapter 2. Ecological Aspects of Physiological Resistance	(39)
Problems of human ecological physiology	(39)
Physiological resistance under Arctic conditions	(44)
Status of physiological resistance in members of polar expeditions	(58)
Clinical/immunological characteristics of acute pneumonia	(67)
Chapter 3. Physiological Resistance in Physical and Psychological Stress	(74)
Stress effects of physical exertion	(74)
Immunogenesis of psychological stress	(83)
Chapter 4. Adaptive Physiological Reactions in Prolonged Hermetic Isolation	(91)
Status of defense mechanisms during changes in work and rest schedule	(91)
Defense mechanisms in exposure to high temperatures and noise	(96)
Mechanisms of resistance in smoking	(102)
Chapter 5. Physiological Resistance in Various Injuries	(109)
Status of defense mechanisms in injuries and their complications	(109)
Changes in defense mechanisms in the post-traumatic period	(113)

## ADAPTATION

- Chapter 6. Mechanisms Underlying Resistance in Combined Exposure to Adverse Factors (126)
  - Biological effects of combined stressors (126)
  - Physiological resistance in adaptation to cruise conditions (129)
  - Hematological criteria for evaluating effects of extreme conditions (138)
- Chapter 7. Principles For Evaluating and Predicting Preclinical States (145)
  - Criteria of adaptive and preclinical states (145)
  - Typological principles of defense reactions (152)
- Chapter 8. Ways to Increase Physiological Resistance (158)
  - Control of the adaptive process (156)
  - Endocrine regulation under exposure to extreme factors (169)
- Chapter 9. Correction of Immunodeficient States (174)
  - Immunotherapy and immunocorrections (174)
  - Regulatory properties of thymosin (179)
- Chapter 10. Prospects for the Future of Bioregulation Therapy (in lieu of a conclusion) (200)
- References (206)

**MONOGRAPH:**

M168(30/91) Gnevyshev MN, Ol' AI(Editors).

Biofizicheskiye i klinicheskiye aspekty geliobiologii: Sbornik nauchnykh trudov; Биофизические и клинические аспекты гелиобиологии: Сборник научных трудов [*Biophysical and Clinical Aspects of Heliobiology: A Collection of Scientific Papers*]

Volume 65 in the series Problemy Kosmicheskoy Biologii; Проблемы Космической Биологии [Problems of Space Biology]

Leningrad: Nauka; 1989.

[229 pages]

**Key Words:** Biospheric Research, Heliobiology, Radiobiology, Geomagnetic Fields, Solar Effects, Cardiovascular and Respiratory Systems, Neurophysiology

**Annotation:** This collection presents the results of research on the effects of solar activity on the Earth's biosphere. Clinical-statistical research on the effect of natural perturbations of the geomagnetic field induced by solar activity is described, as are experiments on animals exposed to weak artificial electromagnetic fields. Other papers consider certain physical processes in water and water systems that are associated with the mechanisms of heliobiological linkages. Tables of certain solar and geophysical indexes are provided. This book is intended for medical personnel, biologists, geophysicists, and astronomers interested in heliobiology.

**CONTENTS**

Foreword (5)

**CHAPTER I.**

**Clinical Observations of the Effects of Geomagnetic Disturbances on Humans**

Deryapa NR, Trofimov AV. Man and the heliogeophysical environment: The problem of physiological reactivity to magnetism (8)

Rozhdestvenskaya YeD, Pyl'skaya OP, Lyamova GV. Heliobiological studies in cardiology as a method for studying the distribution patterns of cardiorespiratory crises and their association with heliogeophysical factors (15)

Novikova KF, Slyar AP, Il'kov LN, Povolotskaya NP, Gavrikov NA. The effects of solar activity on blood coagulation and frequency of subconjunctive bleeding in patients with circulatory pathology (23)

Kachevanskaya IV. The effect of geomagnetic activity on the course of primary glaucoma (36)

Borodulin BYe. Some manifestations of the tuberculosis process in humans and space and cosmoheliogeophysical factors (42)

Usenko GA, Deryapa NR, Kopantsev SI, Panin LYe. The effect of heliogeophysical factors on certain work-related and physiological functions of aviation personnel in Siberia (52)

Samokhvalov VP. Effects of cosmophysical fluctuations on psychological diseases (65)

## BIOSPHERIC RESEARCH

### CHAPTER 2.

#### **Observations of the Effects of Solar Activity on Animals**

Sidyakin VG, Temuryants NA, Mel'nichenko YeV, Korenyuk II. The association between induced activity of neurons in the motor cortex and geomagnetic disturbances (81)

Sidyakin VG, Yanova NP, Bazhenova SI, Arkhangel'skaya YeV. Change in conditioned reflex performance of animals when solar activity increases (87)

Chernyshev VB. Solar activity and insects (92)

Grakovich RI, Milich MV, Kulikova NP. Helioecological aspects of the dynamics of virulent *Treponema* in orchitis in rabbits in 1962-1986 (99)

### CHAPTER 3.

#### **The Effects of Artificial High Frequency Electromagnetic Fields Analogous to Natural Ones on Experimental Animals**

Volynskiy AM. Change in sensitivity of the skin and external mucous membrane in humans and animals exposed to low frequency, low voltage electromagnetic fields (109)

Temur'yanets NA, Yevsta'eva YeV, Mikhailov AV. Characteristics of the development of adaptive reactions in animals exposed to a weak alternating infralow frequency magnetic field (119)

### CHAPTER 4.

#### **The Mechanisms of Heliobiological Effects**

Kislovskiy LD. On the role of critical phenomena in second-order phase transitions in processes of self-organization of biospheric systems not in equilibrium (129)

Zhvirblis VYe. On the replicability of heliobiological experiments (145)

Agulova LP, Opalinskaya AM, Klir'yanov VS. Characteristic features of responses of various subjects sensitive to changes in cosmophysical factors and the effects of artificial weak electromagnetic fields (160)

Kaznacheyev VP, Mikhaylova LO, Ivanova MP, Kharina NI. The role of electromagnetic radiation in intercellular interactions (181)

Kaznacheyev VP, Mikhaylova LO, Ivanova MP, Zaytsev YuA, Kharina NI. Characteristics of growth and behavior of a cellular monolayer in a hypomagnetic field (189)

Kaznacheyev VP, Mikhaylova LO, Ivanova MP, Zaytsev YuA, Kharina NI, Vladimirskiy IB. The effect of a weakened geomagnetic field on sensitivity of cell cultures to poisons (mercury dichloride) (196)

Sokolovskiy VV, Makarov BG, Pavlova RN, Groshkov ES. The unitiol test in investigations of molecular mechanisms of heliobiological associations (200)

Vladimirskiy BM. The sector structure of the interplanetary magnetic field and Piccard chemical tests (210)

Appendix: Tables of solar (W) and geophysical (Ap) indexes (222)

PAPERS:

P1364(30/91) Lyamin VR, Golubchikova AZ, Turbasov VD.

***Bioelectrical activity in cosmonauts' hearts during long-term flights on space station Mir.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 123-124.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Cardiovascular and Respiratory Systems, Bioelectrical Cardiac Activity  
Humans, Cosmonauts  
Space Flight, Long-Term, Mir

**Abstract:** It was found that bioelectrical activity was altered in the hearts of virtually all of 12 cosmonauts, who had completed long-term space flights (from 125-366 days). EKG features were distributed as follows: change in rhythm in 9 subjects, including extrasystolic arrhythmia in 6, sinus arrhythmia in 2, and transitory right atrial rhythm in 1; changes in depolarization phases in 7; changes in the last portion of the ventricular complex in 11 subjects.

In no case was this the first time that such disrupted rhythms were noted in these subjects. In other words, analogous abnormalities had been observed in a number of examinations preflight. In flight, rhythm disruptions occurred, as a rule, when there was a high degree of neuroemotional stress or significant physical exertion, or during performance of provocative tests affecting neural regulation of cardiac activity. It is important to note that cosmonauts experienced no symptoms associated with the extrasystoles, nor were changes in hemodynamic status observed. The total pattern justified classification of these irregularities as functional. In only one instance (that of the engineer of the second prime crew) did extrasystolic arrhythmia lead to unscheduled termination of a flight due to the difficulty in predicting further anomalies.

Changes in myocardial depolarization were mainly expressed in a nonsignificant increase in the amplitude of the QRS complex, occasionally exceeding the upper limits of preflight parameter values.

Changes in the final portion of the ventricular complex were most numerous and varied: decrease in amplitude of parameters was combined in a number of cases with changes in configuration (bimodal, two-phase T peaks, and in two cosmonauts - transitory T inversion). Neither frequency nor severity of changes was directly associated with flight duration. Adverse factors tending to trigger changes included increases in cosmonaut workload and inadequate utilization of prophylactic countermeasures. The leading factor in the pathogenesis of these changes was evidently metabolic shifts in the myocardium, which suggests that prophylactic measures, including the use of cardiotropic drugs, might be beneficial.



P1370(30/91) Turchaninova VF.

***Regional circulation in cosmonauts on long-term space flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Pages: 196

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Cardiovascular and Respiratory Systems, Regional Circulation, Impedance Plethysmography  
Humans, Cosmonauts  
Space Flight, Long-Term, Mir, Prime Crews 3 and 4

Abstract: Poly-impedance plethysmographic studies performed during space flights beginning with the flight of prime crew 3 on Mir included impedance plethysmograms of regions that had virtually not been studied in weightlessness, but which are extremely important for the development of compensatory-adaptive reactions in the vascular areas of the right lung and the liver. In all, 16 examinations were performed on 5 cosmonauts of prime crews 3 and 4 of the Mir space station.

The data obtained showed that in all cases various changes occurred in blood filling and vascular tonus in the lungs with signs of engorgement of the portal system, which serves as an indicator of the state of pulmonary circulation. An impedance plethysmogram of the lung showed elevation of internal vascular resistance to the flow of blood and decrease in elasticity of the trunk of the pulmonary artery as a manifestation of compensatory reactions. The majority of deviations noted increased with increasing flight duration, or, less frequently, were cyclical. The pulmonary impedance plethysmogram of only one cosmonaut (prime crew 3) revealed a hypervolemic pattern and low tonus of the small vasculature. The dynamics of circulatory parameters in the forearm and calf were generally those typically seen under flight conditions, including decreases in pulsed blood filling of calf vasculature and tonus of the small vessels of the forearm, and the establishment of different ratios between analogous parameters (of the arm and leg) from those typically observed on Earth.

The hemodynamic shifts identified gave a relatively clear idea of the nature of adaptation of the circulatory system to space flight conditions, influenced by individual differences and the reserve capacities of each cosmonaut. This has practical significance for support of medical monitoring at various stages of a flight.

P1371(30/91) Fomina GA, Kokova NI.

***Study of the cardiovascular system during the second Soviet-French flight (Ekhokardiografiya Experiment).***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 198-199

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Cardiovascular and Respiratory System, Echocardiography  
Humans, Cosmonauts  
Space Flight, Soviet-French Crew, Mir

**Abstract:** The goal of the Ekhokardiografiya experiment was use of ultrasound methods for in-depth study of changes in central and peripheral circulation throughout a 25-day space flight. The studies were performed using the Ekhografa-2 devices in V, TM, continuous Doppler, and pulsed Doppler modes. Central hemodynamics, myocardial contractility, circulation in the large arteries and veins of the neck and middle cerebral artery, hemodynamics of the legs at the level of the large arteries and veins of the thigh, and circulation in the vasculature of the visceral organs (liver, and kidneys) were investigated. Measurements were made on days 4, 5, 15, 20, and 24 of flight, and also pre- and postflight.

The studies showed decreased size of the left atrium, end-diastolic volume, and stroke ejection volume of the left ventricle in one subject during flight. However, decreased cardiac output was not observed and toward the end of the flight this parameter even increased as a result of increased heart rate. Peripheral vascular resistance decreased. Parameters of myocardial contractility were stable. No significant changes were noted in the pressure index in the pulmonary artery.

During the flight, resistance decreased in the middle cerebral artery, while blood minute volume increased. Resistance also decreased in the renal and common carotid arteries. Postflight these parameters returned to normal by day 3 of readaptation. During the flight there was a tendency for vascular resistance to decrease in the legs. Postflight resistance in the femoral artery increased sharply on day 1 and fell on day 3.

The cross sectional area of the jugular and femoral veins increased continually throughout flight. This was accompanied by decrease in differences in the cross section of the jugular vein in systole and diastole. The changes noted suggest decrease of tonus of the veins during flight. The venous index of the liver, reflecting rate of filling of the right heart, increased significantly at the beginning of the flight and then gradually returned to baseline.

This experiment identified hemodynamic changes that, taken as a whole, attest to the development of relative hypovolemia in microgravity: decreased filling of the chambers of the heart, maintenance of cardiac output by increased heart rate, increased rate of filling of the right atrium, decreased resistance of systemic (decreased total peripheral resistance) as well as regional (brain, kidneys) vasculature. Changes in venous circulation and the state of venous vessels support a hypothesis that the "low pressure" system is more susceptible to the effects of flight conditions. This hypothesis may determine the direction of further research.

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1386(30/91)\* Barer AS, Breslav IS, Isayev GG, Sokol YeA.

***Performance and functioning of the cardiorespiratory system in response to additional resistance to respiration.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 20-22; 1990.

[5 references; none in English]

Cardiovascular and Respiratory Systems, Performance, Function  
Humans, Males  
Resistance to Respiration, Physical Exercise

**Abstract:** This was a study of the human cardiorespiratory system's response to graded physical exercise to exhaustion on a bicycle ergometer accompanied by various gradations of aerodynamic respiratory resistance. Subjects were 13 healthy men aged 22 to 47 who had undergone a long process of adaptation to the conditions of the experiment up to complete stabilization of the parameters recorded. Workload increased every 3 minutes by 30 W until the subject halted the session. The study took place either under conditions of free respiration (R0) or with additional resistance created by inserting a perforated diaphragm in the inspiratory and expiratory tracts of a breathing mask. Gradations of resistance were 12, 16, 20, and 40 cm H<sub>2</sub>O/liter/sec. (R12-R40). Respiratory parameters were recorded using a specially developed flow spiograph connected to the breathing mask. Minute ventilation of the lungs was measured. An electromanometer was used to measure differential of inspiratory and expiratory oral pressure. External respiratory work was computed for 1 minute. Using a mass spectrometer partial CO<sub>2</sub> pressure was recorded in alveolar gas. Mean composition of inspired air was also measured, making it possible to compute minute consumption of oxygen and emission of CO<sub>2</sub>. An electrocardiograph was used to monitor heart rate. The rebreathing method was used at the moment of maximum tolerable exercise to measure cardiac output. These values were used to compute systolic volume of the heart. During the test the subject signalled first when he began to experience respiratory discomfort and then when he could no longer continue to exercise. Each subject's maximal pulmonary ventilation was measured at rest in a 15-second test at varying levels of respiratory resistance.

The level of exercise achieved decreased with increasing respiratory resistance. Oxygen consumption and CO<sub>2</sub> emission, while increasing with exercise, when measured at the point of failure was lower for higher levels of resistance due to the fact that maximum tolerable exercise level decreased as resistance increased. Level of PaCO<sub>2</sub> at failure increased with increasing resistance. The ratio of respiratory work (to overcome additional resistance) to external work (pedalling) remained relatively stable under conditions of respiratory resistance (1.7-1.8% compared to 0.76% under no resistance conditions). Maximum pulmonary ventilation decreased nonlinearly with increasing resistance.

The authors recommend the approach they used here for norming levels of additional resistance to respiration created by a given respiratory apparatus.

Table 1: Respiratory parameters for maximal physical exercise (at moment of failure) and maximum pulmonary ventilation under conditions of various gradations of additional resistance to respiration

Table 2: Cardiodynamic parameters in maximal physical exercise (at moment of failure) under conditions of various grades of additional resistance to respiration

Figure: Endurable levels of additional resistance to respiration as a function of physical exercise

P1390(30/91)\* Luk'yanyuk VYu, Kotovskaya AR, Vil-Vil'yams IF, Novak L, Penaz J, Mikhaylov VM, Pometov YuD, Georgiyevskiy VS, Nikolashin GF, Kuzina VI.

***Use of the Penaz method of continuous noninvasive blood pressure measurement to predict human status during gravity-induced blood redistribution.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 30-34; 1990.

[19 references; 11 in English]

Cardiovascular and Respiratory Systems, Blood Pressure Measurement, Penaz Method, Blood Redistribution

Humans

Acceleration, +G<sub>z</sub>, Tilt Test, Hypokinesia With Head-Down Tilt, LBNP Test

**Abstract:** Three provocative tests were performed to simulate gravity-induced blood redistribution: +G<sub>z</sub> acceleration on the centrifuge, a tilt test, and an LBNP test. Acceleration of 5-G continued for 30 seconds with rate of increase and decrease of 0.2 G/sec. Seven subjects were studied without use of anti-acceleration measures. Nine subjects were exposed to a tilt test at an upright angle of 75° for 20 minutes. These subjects had just undergone 240 days of hypokinesia with head-down tilt (-8°). The LBNP test involved graded levels of depressurization at -25, -35, -40, -50 and -60 mm Hg, with total duration of 25 minutes. There were 11 subjects who had just undergone hypokinesia with head-down tilt (-8°) lasting 7 days. Subjects were 25-45 years old. During the acceleration test, a servotonogram (continuous blood pressure measurement using Penaz' method taken in the finger held at the level of the heart), blood pressure in the shoulder using Korotkov's sounds, an EKG in bipolar chest leads, a photoplethysmogram of the vessels in the earlobe and a pneumogram were recorded. During the tilt and LBNP tests, servotonograms and pneumograms were recorded, and blood pressure was discretely measured in the brachial artery using Korotkov's sounds. The subjects' status was evaluated on the basis of the standard symptoms and from the nature of blood pressure changes recorded using Penaz' method. This method is based on noninvasive recording of blood pressure using an external measurement system under conditions of a relaxed vascular wall. The wall is kept in a relaxed state by continuous regulation of air pressure in a finger cuff using a system of feedback, which makes it possible to quantitatively evaluate minute-by-minute values of systolic and diastolic blood pressure in each pulse oscillation.

At rest before the functional tests, the servotonogram showed rather stable blood pressure in all subjects. Blood pressure measured using Penaz' and Korotkov's methods did not differ by more than ±10 mm Hg. Centrifugation was tolerated well by six subjects and satisfactorily by one. This subject displayed visual symptoms, decreased amplitude of the earlobe pulsogram, and isolated right ventricle extrasystoles. Periodic decrease in pulsed pressure on inspiration recorded by the servotonogram was the first sign of decompensation in this subject. Changes in this subject could not be recorded using Korotkov's method.

Tolerance of tilt was satisfactory in four subjects. The remainder showed poor tolerance, with dizziness, muscle tremor, pallor, and hyperhydrosis of the skin; two showed signs of incipient collapse. Sinus tachycardia reached 129 beats/second, while pulse pressure measured using Korotkov's method decreased to 14 mm Hg. By the first few minutes of the tilt test, Penaz' method revealed pronounced second- and third-order blood pressure waves in subjects with poor orthostatic tolerance. These indicators, which were not always recorded using Korotkov's method, always preceded subjective complaints and objective symptoms of incipient collapse.

Tolerance of the LBNP test was good in four individuals and diminished in seven who could not complete the test. There were two types of symptoms displayed by the low endurance group. In those showing a cardiac type of decompensation, relative bradycardia was observed, coinciding

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

with discomfort, dizziness and nausea, but no changes in blood pressure. In the vascular type of decompensation, systolic, diastolic, and pulse blood pressure dropped. Examination of the servotonogram showed increases in second- and third-order blood pressure waves preceding signs of incipient collapse. Four of the five subjects with vascular decompensation showed decreased amplitude of blood pressure waves with gradual decrease in blood pressure, especially narrowing of the pulse pressure.

The authors conclude that the use of the Penaz method for continuous blood pressure monitoring would allow early prediction of human response to gravity-induced blood redistribution and would be superior for this purpose to discrete methods of measurement.

Figure 1: Dynamics of physiological parameters in subject G. during exposure to +5Gz acceleration at the moment of appearance of visual disturbances

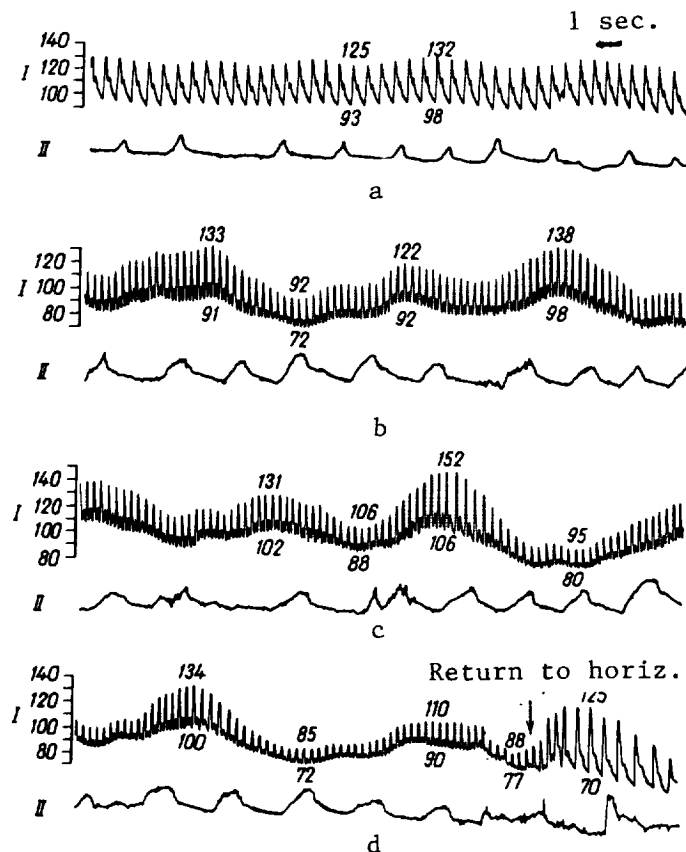


Figure 2: Dynamics of blood pressure measured in vessels of the finger (at the level of the heart) using Penaz' technique in subject S. during a tilt test  
a - baseline (supine); b - minute 4; c - minute 10 of upright tilt; d - minute 20 of the test and return to horizontal position. I - servotonogram with blood pressure computed (systolic on top, diastolic on the bottom); II - pneumogram

Figure 3: Dynamics of blood pressure measured in vessels of the finger (at the level of the heart) using Penaz' technique in subject P. during an LBNP test

P1398(30/91)\* Kazakova GT, Krotov VP.

***State of the pumping function of the myocardium in monkeys after a 7-day period of hypokinesia with head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 56-57; 1990.

[10 references; 2 in English]

Cardiovascular and Respiratory Systems, Myocardium, Pumping Function, Echocardiography  
Monkeys, Rhesus Macaques  
Hypokinesia With Head-Down Tilt

**Abstract:** Echocardiographic measurements were made on three anesthetized rhesus macaque monkeys. Special suits were used to restrain the monkeys in a couch in a head-down ( $-20^{\circ}$ ) position for 7 days. The echocardiogram was recorded of the left ventricle in the M mode from the aorta to the apex along the long axis of the heart, before treatment, on day 7, and immediately after the animals were returned to a horizontal position. The echocardiogram was used to measure size of the left ventricle in systole and diastole. An EKG was recorded at the same time as the echocardiogram. The data obtained were used to compute left ventricle volume, end systolic volume, end diastolic volume, stroke volume, ejection fraction, cardiac output, heart rate, and shortening of the front-to-back dimension of the left ventricle. In addition, the size of the left auricle and thickness of the posterior wall of the left ventricle were measured.

After 7 days in the head-down position, final diastolic volume was significantly decreased, while stroke index, end systolic volume, ejection fraction, and shortening showed a tendency to decrease compared to baseline. Cardiac index and heart rate increased by 11 and 15% compared to baseline, but these differences were not statistically significant. Immediately after return to horizontal position, changes in stroke volume, end diastolic and systolic volume, cardiac index, and heart rate were more pronounced, but only the change in end diastolic volume was statistically significant. Parameters of myocardial contractility, ejection fraction and shortening were unchanged. The animals lost 11% of their weight, and the size of the left auricle and thickness of the posterior wall of the left ventricle were unchanged.

**Table:** Echographic parameters of central hemodynamics in monkeys exposed to 7 days of hypokinesia with head-down tilt

PAPER:

P1387(30/91)\* Kan YeL, Kupriyanov VA.

***The effect of shift work of air traffic controllers on parameters of sympathetic adrenal system activity.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 22-25; 1990.

[12 references; 1 in English]

Endocrinology, Sympathetic Adrenal System

Humans, Aviation Medicine, Air Traffic Controllers

Human Performance, Biological Rhythms, Shift Work, Psychology, Stress

**Abstract:** Subjects of this study were a group of air traffic controllers, aged 25-35 years, working with an automated air traffic control system called "Start" during the morning (9:30-14:00), day (14:00-22:00), and night (22:00 - 9:30) shifts. Epinephrine (E), norepinephrine (NE), dopamine (DA), and DOPA were measured using the trioxindole method in samples of urine taken during the work shift and during a 2-hour period preceding the beginning of each shift. The latter measurement made it possible to evaluate changes in SAS activity during "prestart" activity. The data were compared with control data - parameters of excretion of catecholamines and DOPA in the same controllers during the corresponding period on their days off. Linear correlations were computed.

Excretion of catecholamines was elevated on work days even during the preshift period, consistent with a stress reaction. Effects were less pronounced in the preshift period for the morning shift. The night shift was distinguished by the highest level of stress both in the preshift and shift periods. When subjects were divided into those with high and low baseline values of catecholamine excretion, it was found that those with low values showed increases before and during their shifts, and those with high values (the minority) showed decreases. The latter effect is attributed to inadequacy of the SAS to meet additional needs under stress and is associated with adaptive restructuring.

In analysis of correlations, negative correlation between epinephrine or norepinephrine and DOPA suggest that excretion of catecholamines depletes reserves of the SAS. Such negative correlations were significant before the morning shift, during the day shift, and both before and during the night shift. Positive correlations between epinephrine or norepinephrine and dopamine are considered the most auspicious. Correlations were relatively high and positive before and during the morning shift, low and positive before and during the day shift, and low and mixed negative and positive before and during the night shift. Correlations between epinephrine and norepinephrine were high and positive, suggesting high synchronization of the neural and hormonal components of SAS activity. Preshift epinephrine excretion showed a higher correlation with excretion during the shift than was the case for norepinephrine.

The authors conclude that excretion of catecholamines of air traffic controllers depends not only on workload but on shift worked. The fact that night shifts, while having the lowest workload, were associated with greatest levels of SAS activity justifies the use of prophylactic countermeasures during night shifts.

Table 1: Parameters of SAS activity in groups of air traffic controllers at the Pulkova airport differing in levels of catecholamine excretion

Table 2: Correlation between parameters of SAS activity in air traffic controllers at the Pulkovo airport working on different shifts

P1372(30/91) Kurkina LM, Zabolotskaya IV.

***Cyclic nucleotides in blood and urine of healthy males after long-term exposure to weightlessness and hypokinesia with head-down tilt.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page: 535.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Endocrinology, Adrenergic, Cholinergic Regulation, Cyclic Nucleotides, Adaptation  
Humans, Males  
Space Flight, Long-Term, Hypokinesia With Head-Down Tilt, 370-Day

**Abstract:** Introduction. Cyclic nucleotides are among the major components of the regulatory mechanisms of adaptive-homeostatic responses. The study of cyclic nucleotides during exposure to space flight factors provides information about the state of the cell receptor apparatus, the relationship between the sympathetic and parasympathetic regulatory systems. Long-term exposure to weightlessness was compared to head-down tilt hypokinesia on the basis of level of cyclic nucleotides in blood and urine immediately and in the remote period after exposure.

**Method.** Nine men were studied after a 370-day period of hypokinesia with head-down tilt and 10 cosmonauts were studied after space flight lasting 4-12 months. Levels of cyclic nucleotides - cycloadenosine-3'5'-monophosphate (cAMP) and cyclic guanosine-3,5-monophosphate (cGMP) were measured by radioimmune assay in the plasma of venous blood and daily urine during a baseline period, during hypokinesia and 1, 7, and 30 days after exposure and later.

**Results.** One day after long-term space flights there was an increase in level of cAMP in blood, while cGMP was depressed in the majority of cosmonauts. Thus the ratio of cAMP to cGMP increased, suggesting activation of adrenergic mechanisms of regulation. Seven days postflight, concentration of cyclic nucleotides normalized in the blood of cosmonauts. Renal excretion of cyclic nucleotides was virtually unchanged during the first week postflight.

During the period of strict bedrest, the healthy subjects displayed a definite pattern of changes in cyclic nucleotides in blood, with predominance of the cholinergic mechanisms of regulation over the adrenergic ones, corroborating data in the literature on decrease in sympathetic activity under these conditions. This took the form of a decrease in cAMP and an increase in cGMP in blood throughout virtually the entire bedrest period. Renal excretion of cyclic nucleotides changed little. The greatest changes were noted during the recovery period after 370 days of hypokinesia with head-down tilt: on days 1 and 7, the amount of cAMP and cGMP in blood and urine exceeded baseline by a factor of 2-3. In urine, only cGMP was elevated. In months 1, 2, 8, and 12 after hypokinesia, level of cAMP in blood was no different from the norm, while amount of cGMP remained depressed for 8 months. In the opinion of a number of authors, this suggests decreased resistance to extreme factors. The predominance of the cholinergic regulatory system over the adrenergic in long-term hypokinesia with head-down tilt is probably a consequence of the partial redistribution of body fluids and altered functions of visceral organs, and may play some role in the development of cardiovascular deconditioning. The prophylactic measures (exercise) did not lead to the expected correction of the changes in



## ENDOCRINOLOGY

level of cyclic nucleotides in blood and urine in response to long-term hypokinesia with head-down tilt.

Conclusions: The analysis of concentration of cyclic nucleotides in blood and urine of healthy men showed that 370-day exposure to hypokinesia with head-down tilt, even with prophylactic measures, had a greater effect than long-term space flights.

### PAPER:

P1396(30/91)\* Beloposl'skiy VI, Vergiles NYu.

***A photoelectric method for recording human rotational eye movements.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 51-53; 1990.

[10 references; 7 in English]

Equipment and Instrumentation, Eye Movement Recording, Photoelectric  
Humans  
Neurophysiology, Eye Movements, Rotary

**Abstract:** The authors describe a method they developed for recording rotary eye movements. It is described as being able to measure the vertical meridian of the retina with great accuracy, regardless of the position of the eye in the socket or the position of the head in space. The device contains three major parts: the illumination block illuminates the eye with a homogeneous flow of linearly polarized light; the measurement block transforms the light falling on the eye into an electrical signal proportional to the angle of rotation of a polaroid analyzer (attached to the eyeball with a suction cup); the recording block contains a device for amplifying and recording the signal from the measurement block.

The device was tested in two experiments. The first evaluated the amount of spontaneous rotary type fluctuations of the eye and the contribution of the rotary component when the head is fixed. Experiment 2 measured kinematic characteristics of rotary eye movements when the head was shaken from side to side at varying rates. The results obtained correspond to data in the literature and demonstrate the validity of the photoelectric method for measuring rotary eye movements.

Figure 1: Diagram of the method for photoelectric recording of rotary eye movements

Figure 2: Photograph of subject during use of the photoelectric method for recording rotary eye movements

Figure 3: Samples of records of rotary eye movements with the head restrained

Figure 4: Recording of rotary eye movements when the head is shaken from side to side

## GASTROINTESTINAL SYSTEM

### PAPERS:

P1378(30/91) Polyakov VV, Smirnov KV, Bednenko VS, Ruvnova LG, Afonin BV, Nesterov MA. ***Comprehensive evaluation of the function of the gastrointestinal tract during space flight.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 161-163

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Gastrointestinal System, Organs, Function

Humans, Cosmonauts

Space Flight, Mir

**Abstract:** The set of symptomatic changes in the organs of the gastrointestinal tract under conditions of space flight includes depression of enzyme support of digestive processes in the pancreas and intestine, decreased synthesis of bile acid and other bile components in the liver leading to increased lithogenesis, and changes in the secretory and evacuation functions of the stomach. An in-depth study of the organs of the abdominal cavity was performed at various stages of medical support of space flights.

We developed a set of medical tests of the morphofunctional status of the organs of the gastrointestinal tract while performing a provocative glucose-milk loading test, including estimate of the acid-forming function of the stomach, ultrasound studies of the state of the liver, gall bladder, pancreas, major vasculature of the abdominal cavity, and also study of the dynamics of the blood sugar curve. An on-board apparatus (ultrasound instrument) was used to study the structure of visceral organs and vasculature of the abdominal cavity. An instrument for measuring blood glucose and the "Atsidotest" device were also used. The results were analyzed by the payload specialist during flight and by the principal investigators responsible for the subsequent analysis of primary material.

These studies made it possible to define the characteristics of the morphofunctional status of the organs of the gastrointestinal tract in response to glucose/milk loading in 45 healthy males, aged 18-35. Further testing of this set of analyses within a scientific medical program enabled identification of certain basic characteristics of changes in the status of organs of the gastrointestinal tract in members of the 4th prime crew of Mir.

On day 189 of flight, the payload specialist displayed slow evacuation of food from his stomach, venous hyperemia of the liver and pancreas, manifest in diffuse enlargement of the liver by 1.5 cm and the pancreas (particularly the head by 0.44 cm), in a decrease in exogenous density of the parenchyme of these organs and also in dilation of veins in the spleen and liver and the system of portal veins. There was a relative depression of the blood sugar curve, and retardation of bile evacuation in response to the glucose/milk loading, suggesting a hypokinetic state of the motor evacuation function of the gall bladder.

Postflight changes in the morphofunctional state of the organs of the gastrointestinal tract were somewhat different. Along with normal acidity of the stomach in the payload specialist and

## **GASTROINTESTINAL SYSTEM**

hypoacidity in other crewmembers and persistence of venous hyperemia of the visceral organs, the glycemic curve was elevated due to slowed utilization of blood sugar and a hyperkinetic state of the motor-evacuation function of the gall bladder, manifested in accelerated evacuation of bile in response to loading.

Thus, data obtained in the comprehensive medical evaluation of the organs of the gastrointestinal tract, on the whole, confirm the major hypotheses concerning changes in this system in response to space flight factors and provide essential objective information at all stages of medical support of flight.

PAPER:

P1388(30/91)\* Tret'yakov NV.

***Personality traits of aviation specialists in small working groups with various levels of psychological compatibility.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5):26-27; 1990.

[15 references; 4 in English]

Psychology, Personality Traits  
Humans, Males, Aircraft Maintenance Teams  
Group Dynamics, Compatibility, Leadership

Abstract: A total of 135 four-man aircraft maintenance teams were studied for professional effectiveness and compatibility. Methods used were study of flight documents, ratings, and interviews. Each group consisted of a leader, his assistant, and two other workers. Thirty nine high-compatibility and 37 low-compatibility groups were selected. Group members were given two personality tests the "standardized method of studying personality" (taken from the MMPI) and a 16-factor personality profile. A comparative analysis of results was performed to identify characteristics of individual group members typical of high- and low-compatibility groups.

One commonly encountered (in 40% of the cases) set of traits of leaders of high-compatibility groups included a stable disposition, the capacity to mobilize his resources, a disposition to take risks, and high self-control. A second cluster of traits (encountered in 32% of cases) in leaders of high compatibility groups showed a leader who was good-natured, optimistic, soft-spoken and sensitive in dealing with subordinates. The remainder of the group, particularly the assistant leader, were marked by sensitivity in dealings with others in the work group, high levels of activity, initiative, and persistence in achieving goals. In general, traits were within normal range.

The majority (52%) of low-compatibility groups had members with high anxiety, depression-proneness, tendencies to be overcautious, alienated, and unsociable. In addition, leaders were prone to difficulty formulating their own positions, were dissatisfied with themselves, and tended to blame their problems on others. Such personality characteristics were sufficient to impede performance of even highly skilled professionals. In 21% of the low-compatibility groups, leaders showed a marked tendency to seek excessive domination combined with emotional immaturity and oversensitivity to criticism. Such tendencies were also found in other members of low-compatibility groups. In the assistant leader, traits associated with low compatibility were competitiveness, quarrelsomeness, and tendency to attempt to impose their own ideas on others. Negative traits identified, while beyond normal levels, did not reach the level of pathology.

PAPER:

P1362(30/91) Viktorov AN, Novikova ND, Deshevaya YeA.

***Microflora of the cabin of manned spacecraft and the problem of biological damage to the structural materials used in them.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Pages: 413-414.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Habitability, Biological Damage, Structural Materials, Natural and Synthetic Microbiology, Environmental Microflora  
Space Flight, Spacecraft Cabins, Long-Term Habitation

Abstract: There is a great deal of information in the literature concerning microbiological damage to various polymers, optical glass, fuel, filters, pumps, metals, etc. The development of microbes on materials based on natural and synthetic rubber is associated with decrease in rubber strength and its loss of capacity to serve as a hermetic seal. Multiplication of microorganisms on electronic devices may lead to loss of dielectric (insulating?) properties, leading to short circuits, loss of current, and instability in the operation of various pieces of apparatus. American scientists studying individual construction materials of spacecraft used in Apollo, Viking and Shuttle flights established that microorganisms could use these materials as a nutritive medium and grow on them.

We have identified 94 species of microorganisms in the environment of manned spacecraft, including 58 species of bacteria and 36 species of fungi. A significant number of the identified species are opportunistically pathogenic for humans, and many of these are widely known to be agents of biodegradation with regard to natural and synthetic polymer materials.

Many years of observation of the status of environmental microflora of specific spacecraft have revealed systematic changes in the species composition of the microecosphere formed in them. Thus, during inhabitation of one of the stations, the following conditions of fungi were observed: during inhabitation by the first prime crew, there were 13 species of mycetes; during that of the second crew, 4 species; during that of the third, 8 species. Thus one may speak of a tendency for the diversity of the population of microorganisms to become simpler and for the effects of selection to decrease as duration of spacecraft inhabitation increases; this process is evidently cyclical.

In associations of microorganisms forming on structural materials used in manned spacecraft, ecological competitive advantages have been observed for the fungi species *Penicillium chrysogenum* and *Aspergillus niger* and for bacterial species *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, and *Bacillus polymixa*. In the majority of cases, it is these microorganisms which have demonstrated the capacity to grow on structural materials during long-term inhabitation of space stations. In these instances decorative and insulating materials, the belts of the exercise machines, and one of the windows were also subject to biological damage.

## **HABITABILITY AND ENVIRONMENT EFFECTS**

These data should be considered in the development and incorporation of a special system of countermeasures to protect the spacecraft interior and equipment from biological damage due to microorganisms.

## PAPERS:

P1355(30/91) Sidorenko AA, Chelnaya NA.

***The effect of a 13.5-day space flight on the blood profile and bone marrow of rats.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 341-342.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Hematology, Blood Profile, Bone Marrow

Rats

Space Flight, COSMOS-1887

**Abstract:** Introduction. Exposure of humans and animals to space flight conditions evokes a number of changes in the cytological, biochemical, and physical/chemical parameters of blood and the hemopoietic organs. This work assessed the status of the blood and bone marrow of animals after a 13.5-day space flight on biosatellite COSMOS-1887.

**Methodology.** This experiment used Wistar-SPF line rats. Blood for analysis was taken from an incision in the tail. Concentrations of hemoglobin, erythrocytes, reticulocytes, and leukocytes were measured. The ratios between different types of blood cells were computed in bone marrow smears from the tibia and stained according to the method of Paenheim-Kryukov. Scanning electron microscopy was used to study the morphological characteristics of erythrocytes. Standard methods for preparing samples were used. The preparations were observed with an IEM-100 scanning electron microscope. Bessie's (1974) classification system was used for morphological evaluation.

**Results.** The study of peripheral blood of the animals failed to reveal changes in concentrations of hemoglobin or quantities of erythrocytes. The quantity of reticulocytes was significantly depressed (by 32%,  $p < 0.001$ ). There was a significant increase in the quantity of leukocytes, due mainly to neutrophils (which increased by 26%,  $p < 0.001$ ). Concentrations of lymphocytes and eosinophils did not undergo significant changes. The lymphocyte:neutrophil ratio was 1.24 in the flight group and 4.7 in the control.

The cytological profile of bone marrow revealed a reliable decrease in the elements of the erythrocyte and lymphocyte series. The number of erythroid cells in the flight condition was 24.8%, with 32.6 in the synchronous condition and 33.5% in the vivarium control group ( $p < 0.02$ ). At the same time the percentage of granulocytes in bone marrow of experimental animals was reliably higher ( $p < 0.01$ ) than in both control groups, equalling 43% compared to 36% in the synchronous and 34.4% in the vivarium control condition. In the experimental group there was a reliable increase in elements of the monocyte series ( $p < 0.001$ ). The quantities of eosinophil myelocytes, mast and plasma cells were unchanged in all groups.



## HEMATOLOGY

Analysis of the results of electron microscopic study of the shapes and surface structure of cells showed that the population of erythrocytes of peripheral blood of flight animals displayed a decrease (42% as compared to 78% in the synchronous group) in the number of discocytes and an increase (54% compared to 17% in the synchronous control) of echinocytes in various stages of deformation, primarily the first (40.13%) and second (11.33%) stages. The first stage of echinocytes, according to Bessie's taxonomy (1974), is marked by the thickening of erythrocyte disks, while the second stage involves the appearance of knobs on the surface of the thickened disks. Echinocytes are not a pathological form; nonetheless, their occurrence in increased numbers results either from altered environmental conditions or changes in intracellular processes.

Conclusion. Results of research are in general accord with material obtained previously after shorter and longer space flights.

P1367(30/91) Noskov VB.

***Changes in hematocrit in humans under conditions of long-term hypokinesia and space flight.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 147-148.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Hematology, Hematocrit

Humans

Space Flight, Long-Term, Hypokinesia With Head-Down Tilt, 370-Day

**Abstract:** Introduction. Hematocrit is an indicator of the ratio between the volumes of plasma and blood cells and is an integral parameter of level of hydration and erythrocyte metabolism. Changes in hematocrit reflect dynamics of the liquid component of blood, its cellular composition, and blood viscosity.

**Methodology.** Hematocrit dynamics were studied in 9 subjects undergoing a 370-day period of hypokinesia with head-down tilt ( $-5^{\circ}$ ) and 16 cosmonauts completing flights of up to 1 year in duration. Hematocrit was measured using a centrifuge method with the KOMPUR-100 (FRG) microcentrifuge. For each measurement, two capillary tubes (9  $\mu$ l each) were filled with blood from the finger. As a rule, the results for the two tubes were in complete correspondence.

**Results and Discussion.** Recorded hematocrit values in absolute units ranged from 37 to 50%. To compare the results obtained under conditions of hypokinesia with head-down tilt and space flight, and to account for individual differences, the percentage changes in the parameters were computed for each measurement as compared to the individual baseline. Results of the research showed similar dynamics in the hematocrit value in actual space flight and the simulation. The variability of individual values was lower in space. During the first 6-20 days of exposure to weightlessness or hypokinesia, hematocrit either increased, decreased, or remained the same. Differences were probably due to differences in the rate and severity of individual responses during the early period of adaptation to cephalad fluid shifts. Subsequently during exposure to space or hypokinesia virtually all subjects displayed a decrease in the hematocrit value by 4-14% compared to baseline. No effect of duration of exposure was noted.

From 3-7 days postflight or after hypokinesia, the vast majority of subjects displayed a marked decrease in hematocrit, more pronounced than in flight (13%) or hypokinesia (15%). The dynamics of hematocrit values under these extreme conditions correspond to existing data on decreases in erythropoietic activity, hemoglobin mass, and quantity of erythrocytes in blood. Moreover, these results may be considered a sign of stabilization of fluid-electrolyte homeostasis during relatively long-term exposure to weightlessness or hypokinesia with head-down tilt and as an indicator of decreased blood viscosity under these conditions.

Thus, observation of dynamics of hematocrit parameters makes it possible to evaluate status of fluid-electrolyte metabolism and erythrocyte metabolism and to monitor the course of an individual's adaptation to conditions of long-term hypokinesia with head-down tilt or space flight.

## HEMATOLOGY

P1399(30/91)\* Rodin VV, Voinova II, Volkov VYa, Volkova LA, Moiseyeva YeV, Dozmorov IM.  
***Use of electron paramagnetic resonance to analyze the blood plasma of mice exposed to rotational acceleration combined with ascorbic acid and GABA.***  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(5): 57-58; 1990.  
[13 references; 2 in English]

Hematology, Blood Plasma, Blood Proteins, Metabolism, Lipid Peroxidation, Electron  
Paramagnetic Resonance  
Mice, Males  
Rotational Acceleration, Ascorbic Acid, GABA

**Abstract:** Electron paramagnetic resonance (EPR) has been used successfully to analyze blood plasma for protein. This study attempted to use the technique to analyze the effects of ascorbic acid and GABA on changes in protein shifts in the blood of animals exposed to acceleration. Subjects were male mice divided into three groups: the first was a control group, the second included mice injected with ascorbic acid in a dose of 100 mg/kg body weight, and the third group was injected with GABA in the same dose. Control animals were injected with physiological saline. Each group of animals was divided into two subgroups, each containing five subjects. One hour after injection, one subgroup was accelerated on a centrifuge with a radius of 14 cm with speed of 600 rotations/min for 20 seconds. Centrifugal force created acceleration of 55-G. The other subgroup was not accelerated. Two hours after injection, blood was drawn and centrifuged. Plasma was frozen at the temperature of liquid nitrogen. EPR spectra were recorded. Concentrations of hemoglobin in blood were determined spectrophotometrically. Parameters considered indicative were amount of transferrin ( $g=4.3$ ) and ratio of ceruplasmin to transferrin.

Centrifugation caused amount of transferrin to decrease and ratio of transferrin to ceruplasmin to increase. Administration of either GABA or ascorbic acid normalized these parameters. The authors interpret this as indicating that these two substances prevent increased lipid peroxidation of cell membrane, i.e., heightened activity of superoxide dismutase. This suggests that these "adaptogenic" substances either directly prevent free radical oxidation by acting as "traps" for free radicals, or they mobilize other protective mechanisms in the body.

Figure 1: EPR spectra of the transferrin signal in blood plasma

Figure 2: Amplitude of EPR signals for transferrin and the ratio of ceruplasmin to transferrin in blood plasma

### PAPERS:

P1383(30/91)\* Ponomarenko VA, Rysakova SL, Turzin PS.

***Information interaction between operator and computer during exposure to adverse environmental factors.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,

24(5): 10-13: 1990.

[6 references; none in English]

Human Performance, Man-Computer System, Information Interaction, Psychology, Problem Solving

Humans, Air Traffic Controller

Noise, Light Flashes

**Abstract:** A simulator was used to model problem-solving processes of an operator working in air traffic control under exposure to various types of external interference. The problem task involved obtaining information related to control of objects, categorizing and ranking them on the basis of a series of logical rules, and performing visual transformation operations. A total of eight operators participated, each of whom had fairly well developed skills in solving problems of this type. The task material was displayed on a screen, with screen refreshing occurring every 20 seconds, and commands given orally. External stressors were ranked on the basis of their danger to humans. Class 1 factors involved exposure to: a) noise (until occurrence of unpleasant sensation); or b) light flashes (up to the point of short-term blinding). The second class involved combined exposure to noise and light flashes. Not only the nature, but also the intensity and regularity of the stress factors were varied. The operators were psychologically prepared for the interference factors. The level of psychological motivation of subjects was high and they were considered to be applying maximum effort. However, due to the aversive nature of the stressors their escape motivation was also high. Operators were given tasks at four levels of difficulty. Difficulty was a function of the size of the set of information signals, and the contents and algorithms for mentally reconstructing the initial situation on the screen. The total time and quality of task performance were rated, as were separate components of the tasks. In addition, operators were asked to rate their stress on a six-point scale. A number of psychophysiological parameters (heart rate, respiratory minute volume and rate, GSR) and electrooculographic parameters were recorded.

Inclusion of stress factors produced significant changes in the parameters of operator performance. Time to complete tasks at all complexity levels decreased sharply, especially under exposure to noise and noise combined with light flashes. On the other hand, interference decreased the quality of work; most affected were the verbal components of decision-making and the capacity of the operators to perform visual transformations. These operations were based on application of rules or required utilization of additional knowledge. The most resistant to stress were the more determined stages of performance, utilizing formalized vocabulary and automated skills. Psychophysiological parameters were not correlated with performance parameters. Addition of stressors to the situation was associated with 30-50% increases in a number of the parameters (heart rate, cardiac output, respiration rate, GSR, and blink rate) followed by decrease. Self-evaluation of stress and performance characteristics were not always correlated.

## HUMAN PERFORMANCE

P1389 (30/91)\* Yepishkin AK.

***Physical and psychogenic effects of impact acceleration on operator performance in a tracking system.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 28-30: 1990.

[6 references; none in English]

Human Performance, Tracking Performance, Psychology, Anticipatory Stress  
Humans, Males, Individual Differences  
Acceleration, Impact

**Abstract:** The objective of this work was to study the effect of impact acceleration on sensorimotor tracking. Nine healthy males, aged 18-20, participated in the study. Impact acceleration in the head-pelvis (+G<sub>z</sub>) direction ranged from 10-16-G. Each subject was exposed to impact up to six times once or twice a day, with an interval between exposures of 2-4 days. The tracking task involved predictive tracking of a sinusoidal signal recorded graphically. Parameters measured included tracking errors and reaction time to changes in signal frequency. Measurements were made 5 minutes before and 5 minutes after exposure to impact. Heart rate was recorded 30 and 5 minutes and 5 seconds before acceleration and 5 seconds and 5 minutes after it. Although this is not stated in the paper, subjects apparently knew when they would be exposed to impact.

Impact itself was followed by increase in tracking errors, and reaction time in task performance. Anticipation of impact lead to even greater disruption of operator performance and increases in heart rate. A manipulation increasing stress, while having no physical effects on impact, further enhanced the anticipatory responses. If subjects showed a greater disruption of performance after impact than before it, anticipatory stress to each successive exposure to acceleration began to diminish after 2 or 3 exposures. If, however, anticipatory stress was initially greater than effects of impact, this "adaptation" effect did not occur (or was diminished) on later trials.

Table: Changes over trials in heart rate and tracking performance parameters

Figure 1: Characteristics of sensorimotor tracking and dynamics of heart rate in subjects before exposure to impact acceleration

Figure 2: Characteristics of sensorimotor tracking and dynamics of heart rate in subjects before exposure to impact acceleration in a closed cabin

Figure 3: Two types of heart rate and tracking performance parameter dynamics in subjects anticipating impact acceleration

Figure 4: Two types of heart rate and tracking performance parameter dynamics in subjects after impact acceleration

## PAPERS:

P1365(30/91) Lesnyak AT, Vorotnikova IYe, Mitirev GYu, Samoylova RS.

***Phenotype properties of human lymphocytes in weightlessness and hypokinesia studied using monoclonal antibodies.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 118-119

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Immunology, Lymphocytes, Surface Antigens; Monoclonal Antibodies

Humans, Cosmonauts

Space Flight, Long-Term, Short-Term Hypokinesia With Head-Down Tilt, 370-Day

Abstract: The data currently available attest to depression of the immune response in cosmonauts soon after return to Earth and in subjects undergoing long-term hypokinesia with head-down tilt. The most common change occurs in the T-cell components of cell-based immunity, composed of functionally distinct cells that mediate and regulate the immune response. The use of modern methods for researching the surface antigens of lymphocytes using monoclonal antibodies enables quantitative evaluation of subpopulations of T-cells, and makes it possible to approach an understanding of the mechanisms underlying disorders, in order to find a way to correct and prevent them.

The goal of this research was to produce a phenotype description of peripheral lymphocytes in 11 cosmonauts preflight and after 8-, 151-, 241-, and 366- day flights, and also in 6 subjects undergoing a 370-day period of hypokinesia with head-down tilt. Subpopulation analysis was conducted using fluorescently labelled monoclonal antibodies specific to the following surface antigens of lymphocytes of human peripheral blood: CD3<sup>+</sup> (mature T-cells), CD4<sup>+</sup> (helpers/inductors), CD8<sup>+</sup> (suppressors/cytotoxic cells), and CD25<sup>+</sup> (activated cell with a receptor for interleukin-2; measured only in cosmonauts). Luminescent microscopy and flow cytophotometry were used.

When cosmonauts were studied during the preflight period, 83.4±44.4% of the cells had CD3<sup>+</sup> antigens, 54.1±22.9% had CD4<sup>+</sup> antigens, and 39.3±16.3% had CD8<sup>+</sup> antigens. Cells with a receptor for interleukin-2 (CD25<sup>+</sup>) were only present in isolated instances. In four cosmonauts who were studied three times during this period the coefficient of variation was a mean of 12.7% for CD3<sup>+</sup> lymphocytes, 14.8% for CD4<sup>+</sup>, and 29.0% for CD8<sup>+</sup>.

On day 1 after the 8-day flight, one of the two cosmonauts studied showed a tendency for the helper:suppressor ratio to decrease. After the 151-day flight, on day 1 proportion of CD25<sup>+</sup> lymphocytes was 5.3 and 6.7% in the two cosmonauts studied. On day 7, this proportion was 10.2 and 1.9%, respectively. In the cosmonaut completing a 241-day flight, there was some decrease in concentration of T-helpers on day 1 (to 21.2%) with a helper:suppressor ratio of 0.6. On day 7 postflight there was a tendency for concentration of T-suppressors to increase (39.3%) with a helper:suppressor ratio of 0.9. At these measurement times, CD25<sup>+</sup>

## IMMUNOLOGY

lymphocytes occurred at levels of 1.4 and 2.9%, respectively. In the two cosmonauts who flew for 366 days, concentration of CD25<sup>+</sup> lymphocytes on day 7 was 9.4 and 7.4%, while after 2 months this value was 2.0 and 5.4%, respectively. The helper:suppressor ratio on day 7 was 1.5 and 1.0, while 2 months postflight it was 1.0 and 1.2, respectively.

In subjects undergoing long-term hypokinesia with head-down tilt, the quantity of mature T-lymphocytes was not altered significantly. Level of T-helpers showed a tendency to decrease on day 120 of hypokinesia in the majority of subjects. T-suppressors were elevated in subject G on days 204 and 300 of bedrest. During the recovery period there was some tendency for level of T-suppressors to decrease: in subject S on day 7 and in all subjects of group B on day 60.

Thus during the immediate postflight period, lymphocytes with signs of activation (CD25<sup>+</sup>) occurred in the peripheral blood of some cosmonauts. There was also a tendency for the helper:suppressor ratio to decrease. Some subjects exposed to long-term hypokinesia with head-down tilt displayed an increase in number of T-helpers on day 1 and a tendency for T-suppressors to increase during the subsequent period. Late in the recovery period the concentration of T-suppressors decreased.

P1368(30/91) Serov IV, Chaffar L (France), Konstaninova IV, Breytmayer ZhF, Mani S (France), Zarayskin YeL, Ferrois B (France).

***Production of the major mediator of immunity, Interleukin-2, and expression of IL-2-receptors by lymphocytes in cosmonauts after flights on space station Mir.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 174-175.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Immunology, Interleukin-2, Lymphocytes  
Humans, Cosmonauts  
Space Flight, Short-Term, Long-Term. Mir

**Abstract:** Decreased reactivity of T-lymphocytes has been noted in cosmonauts after space flights of the Soyuz, Mir, and Spacelab stations and the Space Shuttle. These deviations attest to increased risk of occurrence of a number of bacterial, viral, and autoimmune diseases. If we are to develop adequate prophylactic countermeasures for disorders in immune response in space flight, we must understand the mechanisms of these changes.

The authors studied the effects of short- (8-10 days) and long-term (65-366 days) flights on the production of the major humoral mediator responsible for the proliferative activity of T-cells, interleukin-2 (IL-2), by the lymphocytes of cosmonauts. In some of the observations, expression by the lymphocytes of cellular receptors to IL-2 was also measured. Material for the research was mononuclear cells isolated from the blood samples of 19 cosmonauts, which were taken several times pre- and postflight. Synthesis of lymphokines was induced *in vitro* using phytohemagglutinin. The STLL IL-2-dependent cell line, 7-day-old human lymphoblasts, and depleted 10-day-old unstimulated human lymphocytes were used as a test system in biological testing of IL-2. Quantity of IL-2 produced was evaluated using immunoenzyme analysis (ELISA) with monoclonal antibodies to recombinant IL-2 using the concurrent inhibition or the sandwich method.

The biological activity of the IL-2 was depressed postflight in 17 of 19 cosmonauts. After long-term flights, level of IL-2 in some cosmonauts was decreased by half, in others it was only 4.7-14% of preflight level. After a week some cosmonauts showed a tendency for these parameters to normalize. Suppression noted after short-term flights was less extreme.

Immunoenzymatic analysis performed in eight cosmonauts did not reveal any decrease in the level of IL-2 produced. Expression of receptors to IL-2, which was evaluated using cytophotometry with monoclonal antibodies, was unaltered postflight.

This study established that the decreased functional activity of IL-2 observed postflight was not accompanied by decreased IL-2 production. Evidently the effects observed reflect disruption of the regulation of the immune system during space flight.



## IMMUNOLOGY

P1375(30/91) Konstantinova IV, Lesnyak AT, Antropova YeN, Rykova MP, Meshkov DO, Vorotnikova IYe, Serov IV, Uchakin PN.

***The human immune system in response to a 1-year period of hypokinesia and long-term space flight.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health  
Page 101.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Immunology, Immune Status, Musculoskeletal System, Bone, Metabolism, Calcium Metabolism  
Humans, Males, Cosmonauts  
Space Flight, Salyut-7, Mir, Long-Term, Hypokinesia With Head-Down Tilt, 370-Day,  
Prophylactic Countermeasures

Abstract: The immune system plays an essential role in supporting physiological homeostasis. Immunological mechanisms control the antigen stability of the *milieu interieur* and provide protection from bacteria and viruses. They are associated with regulation of the functions of a number of organs and tissues, participating, in particular, in regulation of calcium metabolism in bone tissue.

Space flight conditions induce a number of deviations in immune mechanisms. Thus, to evaluate the feasibility of future increases in duration of manned space flight we must investigate immune response to appropriate ground-based simulations of flight.

An experiment using a 370-day period of hypokinesia with head-down tilt investigated the effect of long-term bedrest on immunity and the efficacy of the set of prophylactic countermeasures employed. Data measured over the course of the hypokinesia period were compared with the status of immune parameters in nine cosmonauts after the longer flights (211, 237, 241, 327, and 365 days) on space stations Salyut-7 and Mir.

It was shown that the long-term exposure of 10 healthy subjects to hypokinesia with head-down tilt leads to a number of changes. While the increase noted in T-lymphocytes in blood was moderate, there was a profound decrease in the capacity of these cells to be activated *in vitro* in the presence of mitogens, as measured radiometrically from the index of proliferation, and radioautographically on the basis of RNA synthesis in lymphoid cells. An increase in the concentration of active T-lymphocytes and a tendency for the level of B-lymphocytes to increase were established.

During hypokinesia with head-down tilt, the quantitative and functional characteristics of cellular antiviral immunity periodically decreased. The capacity of lymphocytes to produce alpha-interferon decreased, while production of gamma-interferon remained high. Beginning in month 2 of hypokinesia there was a reliable increase in the production of osteoclast-activating factor by blood leukocytes. Changes in many parameters were more extreme toward the end of the 370-day period of hypokinesia; on day 1 of the rehabilitation period these deviations persisted, and subsequently gradually normalized. The rate of recovery of parameters indicative of various components of immunity varied from 7 to 60 days.

## IMMUNOLOGY

After space flights lasting from 7-12 months, there were decreases in the activation and proliferation capacity of lymphocytes, as well as suppression of parameters of antiviral immunity. Production of the major mediator of immunity - interleukin-2 - was also suppressed, to the greatest extent after the longest flights. Comparison of the effects of actual space flight and hypokinesia showed that ground simulations induced a number of deviations close to those observed in cosmonauts postflight; however, the changes occurring in actual flight were more extreme as a rule. The simulation experiment revealed immune system responses differing in nature and rate of adaptation from those occurring in space. It was established that under conditions of weightlessness and its simulation changes occur in the response of the T-cell component of immunity. These deviations attest to an increased risk of a number of infectious and noninfectious diseases.

Production of osteoclast-activating factor, studied in eight cosmonauts after flights of varying duration, was reliably elevated in three subjects; in one after a long-term flight (327 days), and in the two others after flights lasting 65 and 8 days. A detailed analysis of the dynamics of increased production of osteoclast-activating factor in the experiment involving a year-long period of hypokinesia with head-down tilt, similar to those identified in initial observations of cosmonauts, suggests the need for prophylactic countermeasures that target the immunological mechanisms for regulating this process to protect against loss of calcium in bone tissue in weightlessness.

P1380(30/91) Rykova MP, Meshkov DO.

***The natural cell-mediated cytotoxicity system in hypokinesia with head-down tilt 370 days in duration.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Pages: 169-171.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Immunology, Cell-Mediated Cytotoxicity, Antiviral Immunity  
Humans, Males  
Hypokinesia With Head-Down Tilt, 370-Day

**Abstract:** Research performed over a number of years has demonstrated the effect of the set of space-flight factors on antiviral immunity in humans. If flight duration increases further, decreases in the functioning of the immunocompetent cells facilitating antiviral immunity may become pathogenetically significant. Thus, the continued improvement of ways to prevent and correct disruption of the immune response in humans are of pressing importance. Development of specialized methods of immune correction requires a detailed analysis of the cellular mechanisms of antiviral immunity in humans exposed to simulations of various effects of weightlessness. The goal of this research was to study the effects of a 370-day period of hypokinesia with head-down tilt on cytotoxic activity of lymphocytes.

Nine apparently healthy males, aged 27-42, exposed to a 370-day period of hypokinesia with head-down tilt served as subjects. They were divided into two groups. The first group (n=4) underwent a complex program to prevent adverse effects of the treatment, including physical exercise and the use of certain pharmacological preparations, starting on the first day of treatment. Subjects in the second group did not start the prophylactic program until day 120 of strict bedrest, after which the two groups were treated identically. Immunological studies were performed late in the baseline period, on days 60, 100, 204, 230, 290, and 350 of treatment and on days 1, 8, 28, and 60 of the recovery period. The following parameters indicative of cell-mediated cytotoxicity were measured: functional activity of natural killer lymphocytes (NK), measured using a 16-hour <sup>3</sup>H-uridine membrane toxicity test; natural cytotoxicity of lymphocytes at the level of single cells, evaluated on the basis of formation of conjugates with target cells, and also on the basis of death of conjugate cell targets; and lectin-induced cellular cytotoxicity.

The research performed showed that during the first 10 months of hypokinesia, functional activity of NK was reduced at one measurement point or another in all subjects. These changes were reversible; in the majority of subjects, temporary depression of membrane toxic activity of NK was followed by recovery of the cytotoxic capacity of the NK. Indeed, in some subjects the index of cytotoxicity even rose (above baseline) for a short period of time. During the final period of hypokinesia (day 350) and on day 1 after return to normal conditions, virtually all subjects displayed a decrease in NK functional activity, with the parameter returning to normal on day 7 of recovery.

## IMMUNOLOGY

Analysis of NK activity at the level of single cells showed that the capacity of NK to form conjugates with target cells and the cytotoxicity of the NK within the conjugates decreased in eight of the nine subjects. The percentage of "active" NK in the population of lymphocytes decreased significantly on days 110 and 204 of treatment and on days 8 and 28 of recovery.

Lectin-induced cellular cytotoxicity was depressed on day 350 of bedrest and day 1 of recovery in virtually all subjects; on day 7 of recovery some of the subjects displayed normalization of this parameter.

Comparison of the two groups of subjects revealed no significant difference in natural cytotoxic activity of lymphocytes.

Thus, long-term exposure to hypokinesia with head-down tilt leads in humans to a decrease in antiviral immunity. Comparison of the properties of natural cytotoxicity studied suggested that an important role in disruption of NK activity is played by decreased levels of lymphocytes capable of "recognizing" target cells, decreased capacity to form stable conjugates and to lyse the cells, as well as by diminished NK recycling capacity.

PAPER:

P1363(30/91) Geodakyan RO.

**A substrate for long-term cultivation of plants in inhabited spacecraft.**

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 417-418.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Life Support Systems, CELSS, Space Greenhouses  
Botany, Plants, Lettuce  
Substrate, Balkanin, Zeolite, Humus

Abstract: An essential issue in developing the higher plant components in closed ecological life support systems in future space greenhouses for long-term use is to find a long-lasting substrate. Such a substrate is required if continuity of cultivation of generations of plants is to be provided without correcting the biogenic elements in a closed ecological system. In the past the substrates used in artificial conditions for plant cultivation have included ion-exchange resins, and zeolites, but they supported high plant productivity for only two to three growth cycles due to accumulation of root secretions, the products of incomplete decay of root fragments, and metabolites of microorganisms. The composite substrate we developed was based on Balkanin, a salt-saturated natural zeolite of Bulgarian origin. The inclusion of biologically active substances from humus (ecotol) allowed us to increase the duration of substrate usefulness to seven growth cycles for lettuce and radishes. However, in this case the plants also died due to disruption of ecological regulatory mechanisms in the root area.

The goal of this work was to select and study new composite substrates to support high productivity of plants.

Experiments were performed on three substrates: Balkanin, a salt-saturated natural zeolite of Bulgarian origin to which was added black earth soil; or leaf humus; or a mixture of leaf humus and river sand. All the substrates were matched in concentration of nutritive elements. The substrates were placed in 4-kg containers with a planting area of 0.045 m<sup>2</sup> and a height of 0.12 m. In each container there were two plants of *Basella rubra* from the Cruciferae family, a perennial tropical lettuce, which is very productive and has a good regeneration capacity. The plants were harvested at a height of 15 cm from the surface of the substrate by cutting the new shoots three times a week; the number of shoots was counted and their length, number of leaves, dry and fresh weights were determined.

Results showed that the least biomass (3.3-7.8 g/m<sup>2</sup>/day) was obtained from the plants grown on a mixture of humus and sand, due to unfavorable air and water properties of the substrate. The highest plant productivity at the beginning of the experiment occurred for plants grown on Balkanin combined with soil, reaching 32.5 g dry mass /m<sup>2</sup>/day on day 110. However, during the second half of the experiment productivity on this substrate decreased sharply; on day 250 the condition of the plants worsened and the experiment was terminated. When the Balkanin substrate was combined with leaf humus, biomass increase was more stable over the course of

## LIFE SUPPORT SYSTEMS

310 days and fluctuated in the range of 15.6-27.0 g dry mass/m<sup>2</sup>/day, and over the course of the experiment the dry biomass was 35% greater than that obtained from plants grown on Balkanin and soil substrate. The higher productivity of Balkanin mixed with humus compared to the analogous substrate mixed with local soil evidently was due to a qualitative difference in the organic substances contained in the two substance — with respect to how readily they could be assimilated by the plants. In conclusion, it must be noted that perennial vegetables proved superior to annuals — the specific productivity of the tropical lettuce that was used exceeded by a factor of 2-3 all the traditional annual lettuce plants studied.

Thus, the new composite substrate Balkanin mixed with humus supported continuous cultivation of plants without a decrease in their productivity, and the duration of use without substrate replacement increased to 9-10 months. The proposed composite substrate is suitable for use in space greenhouses.

## LIFE SUPPORT SYSTEMS

### Special Feature: *The Quails That Flew In Space*

Translation of article in Moskovskaya Pravda: 15 September 1990

Key Words: Life Support Systems, CELSS, Birds, Quail, Developmental Biology, Space Flight, Mir, Botany, Space Greenhouse, Lettuce, Radishes

As we all know, Japanese journalists have just flown in space. However, one specialist in space medicine told me, with a good-natured grin, that Japan's national prestige was already at an all-time high: hadn't the journalists been preceded in space by Japanese quails? He was implying that Japanese superiority had already been demonstrated -- the Japanese quail is considered the highest quality breed of quail.

"Our experiments, which at first glance may seem romantic," said Doctor of Biology G. Meleshko, "began a quarter of a century ago. The basic concept was that human beings in space should be made to feel as if they are still on Earth. The cold metal walls of the spacecraft, the food which has to be squeezed from a tube like toothpaste, the smells characteristic of a latrine — none of this is conducive to feeling at home."

Yes, and in general we know precious little about what a human requires to live a human life. The minimal set includes only water, food, and oxygen. Man needs woman (and the cosmonauts have to do without in flight). And what else? What do we know about water, for example? Even Vernadskiy said that this is not merely the substance described by the formula  $H_2O$ . Water has always been the habitat of a large number of organisms and each one leaves traces in the medium. And yet our understanding of water today is more or less on a par with that of the average inhabitant of the ancient world.

Nor do we have any better understanding of how similar to the Earth the conditions of space flight have to be in order to prevent cosmonauts from losing the capacity to live and work. Yet such an understanding is essential, especially when we consider future flights, for example, to Mars. What if the cosmonaut approaching this planet, who has long been deprived of the food he is accustomed to and the morning sounds of his favorite dog barking, decides to become a permanent satellite of Mars? The experts cannot preclude the possibility of something like this occurring. What if suddenly a cosmonaut begins to dream every morning about the chickens in the yard of his boyhood home, after which the only way out is to embark on an EVA without a space suit?

There are different opinions on this point. The engineers believe that all this is a fantasy. The biologists and psychologists do not want to allow long-term flights in the absence of a biogenic environment of the kind humans are accustomed to.

Research on this topic began at the time of the first space flights. Experiments were performed by both Soviets and Americans on animals and plants, rather unsystematically and, for a long period of time, unsuccessfully. The fact that this problem is one of the most important in the development of cosmonautics appears to be acknowledged only by those who are working on it. Most often it is perceived as a gratuitous (in the literal meaning of the word) addendum to serious space science. In the United States this research direction was even eliminated and was only resurrected 5-6 years ago, when it became obvious that interest in it was far from merely academic.

Throughout this whole period, work on this problem at the Institute of Biomedical Problems in Moscow did not cease, although from time to time it nearly stopped, only to be resumed with renewed energy. In test tubes and flasks, scientists studied the problem of life and of biological

## LIFE SUPPORT SYSTEMS

subjects in space. There was, it is true, one hermetically sealed enclosure, constructed at the behest of Korolev, for ground-based experiments on humans. It was 5 cubic meters in size, about the same as the Vostok spacecraft, which was its contemporary. For a long time it stood on the staircase in the Institute, until the fire inspectors exercised their veto power. The enclosure was taken out into the yard and soon more or less ceased to exist.

Nevertheless, our scientists have now obtained such results that America — here's an unusual turn of events — will find it very difficult to catch and outstrip us in this area. The distance, it is true, is now catastrophically diminished.

The Americans have started work with their characteristic decisiveness. There already exists a national program devoted to this area. The 5 cubic meters of our research enclosure can be contrasted with a hothouse or greenhouse — I don't know what to call it in light of its enormous size — a hectare in size and 8 meters in "height," enclosed by a structure made of a material that, judging from its utilization factor, is beyond the reach of our own materials science. The structure will contain representatives of all conceivable components of the biosphere: deserts, forest, savannah, swamp, seashore, agricultural areas. Birds from all latitudes will fly through it. On the other hand, our own scientists, have done a fair to middling job of sending quails into space and constructing a mini-greenhouse on a space station. Their American colleagues, I repeat, are far from this point.

"Why were Japanese quails, in particular, chosen for such an honor?" I asked the program director, G. Meleshko.

"Their energy utilization factor is the largest of any animal. Moreover, they are good layers. During the early legs of long-term flights, plans call for the cosmonauts to eat eggs, not meat. Imagine: a fresh egg for breakfast. Quail eggs have the advantages of being high in calories and nutritious, and even more important, they are sterile. And the shell of their eggs, unlike that of other birds, is rather strong, capable of withstanding acceleration. And, finally, they are very tasty."

The incubator equipment, developed by our specialists working with the Czechoslovaks, is intended for a complete developmental cycle from quail egg to mature bird, with production of new eggs. The incubator guarantees, in romantic terms, that the humans will have other living creatures as companions, or, in practical terms (some people prefer them), that they will have fresh eggs to eat.

In March of this year, the incubator and the eggs were delivered to the station and the equipment turned on. Seventeen days later, right on schedule, baby birds hatched. Six hatched and scrambled valiantly out of their eggs themselves, but two were unable to emerge and died. Two others almost died of grief — Anatoliy Solovyev and Aleksandr Balandin — who had tried desperately to save the birds.

The cage in which the birds were placed appeared to be well adapted to their needs. It had a grid "floor" (the designation of one wall as the floor is purely arbitrary) with an airstream directed at it, which was supposed to serve the function of the column of the atmosphere (i.e., hold the birds on the ground). The squares of the grid corresponded to the size of the birds' feet and the scientists hoped that, as had occurred in experiments on the ground, the birds would hold on to the grid with their claws and thus stand firmly on their legs.

However, this system did not work — the chicks began to somersault in weightlessness like wind-up toys, and one can only conjecture what they felt at the end of their first day of life. (Did they know that life was not always such a merry-go-round? Did they know that millions of their ancestors lived otherwise?) The asymmetry of their bodies and the incessant flapping



## LIFE SUPPORT SYSTEMS

of their wings only exacerbated their somersaulting. The cosmonauts wrapped them in napkins, and held them down on the grid floor. Nothing helped! While they were rotating in the air, the chicks could not get close enough to the food dispenser to eat. Their peeping was loud enough to be heard on the ground.

The lives of the chicks ended tragically. They were immersed in a special solution of alcohol and glycerine — causing instantaneous death. Now they are back on Earth, and the scientists studying them will soon be able to describe the process of their embryogenesis.

These results are truly unique. Would adult birds succeed where the chicks failed? Before the experiments could continue, this question had to be answered. Academician Bodya from the Institute of Farm Animals in Bratislav developed a special vest for individual restraint. These vests serve to keep the birds near their food dishes. And four more quails were sent into space. En route, during the second orbit, one of them laid an egg.

Alas, after they arrived at the station, the female birds went on strike and laid no more eggs. There was not a single strikebreaker throughout the remainder of the flight, and 1 week later they returned to Earth along with the cosmonauts.

As children, the majority of us were firmly convinced that a chicken lays eggs because from time to time the rooster makes love to her. Many still believe this. For these people, the information that the lady quails ceased to lay will not seem surprising. Indeed, there wasn't a single male quail in space. But this was not where the trouble lay. Dissection on the ground revealed that the oviducts had undergone atrophy. But it was also significant that the birds in the synchronous control group, which were also exposed to vibration and acceleration in the laboratory at the same time as the flight animals, also ceased to lay. Evidently, both groups of quails had undergone severe stress. And that is not difficult to understand.

"And so there was another failure?" I asked G. Meleshko.

"On the contrary. We learned of the inadequacy of short-term experiments. After all, for these 8 days, we were observing in essence not the effects of weightlessness, but of the stress that the birds experienced when they were put into orbit. The duration of the experiment proved to be inadequate for them to recover."

"And how did they do after they returned to Earth?"

"They began to lay eggs regularly. Those who had flown began to lay on day 8, and those who awaited them on the ground started on day 7 after the first group returned to Earth. The eggs were placed in an incubator and currently four chicks have hatched. The egg laid in space produced a normal chick."

At the same time another important experiment was going on in space. There was a greenhouse on board. A small vegetable garden! Lettuce and radishes were cultivated. At their latest press conference, both cosmonauts repeated more than once that the greenhouse was a great source of pleasure for them during their flight.

The equipment for the greenhouse was developed in the Institute of Space Research of the Bulgarian Academy of Sciences and everything involved in the program worked ideally for 53 days and nights. For the first time, cosmonauts received fresh root vegetables in space. Until now it was not known whether the flow of metabolic substances from the leaves into other portions of the plant would occur in weightlessness. In other words would the radishes be able to grow?

## **LIFE SUPPORT SYSTEMS**

They grew! It's true that the time required for them to develop increased and their productivity decreased. We still have to find out why this occurred, but in the main the experiment was a success. The cosmonauts, they report, zealously kept watch over each other to ensure that the products reached the consumer, in this case, the scientists on the ground. It is true that one radish didn't make it -- the cosmonauts ate it.

These were the first experiments on equipment which proved to be able to support the growth and development of plants and birds in flight. Science had never done anything similar before: they had always limited themselves to simpler experiments.

And new quails will fly in space at the end of the year (1990). And this time, scientists say, the experiment will be complete -- from placing the eggs in the incubator to laying of new eggs.

## MATHEMATICAL MODELING

### PAPER:

P1397(30/91)\* Nosovskiy AM, Pravetskiy NV, Matrosova MA, Kholin SF, Shakin VV.  
***Mathematical rationale for determining a sufficient number of measurements for reliable evaluation of recorded parameters in space biology and medicine.***  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(5): 53-56; 1990.  
[7 references; none in English]

Mathematical Modeling, Number of Measurements  
Experimental Design, Statistical Reliability  
Space Biology and Medicine

Abstract: The authors describe the standard method for determining an adequate number of observations to reliably approximate a true population mean based on Student's t distribution. They suggest that this method be used in space biology and medicine.

PAPERS:

P1376(30/91)Markin AA.

***Lipid peroxidation: 1-year space flight and its ground-based simulation.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина.Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine:

IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 537.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Metabolism, Lipid Peroxidation, Adaptation

Humans, Cosmonauts

Space Flight, Mir, 1-Year, Hypokinesia With Head-Down Tilt, 370-Day

**Abstract:** Introduction: The universality of the lipid peroxidation response and the high biological activity of its products make it possible to use the characteristics of lipid peroxidation as indicators of the stability of metabolism, reflecting adaptive potential. It is thus of interest to study lipid peroxidation in cosmonauts after a 365-day space flight and in subjects in an experiment involving 370 days of hypokinesia with head-down tilt, a widely used simulation of the effects of weightlessness.

**Methodology:** Two groups of volunteers participated in the 370-day hypokinesia with head-down tilt experiment. In group A (n=4), a set of prophylactic countermeasures against the adverse effects of the treatment was used from the beginning of the experiment; in group B (n=5) the measures were utilized beginning on day 120 of treatment. After a 365-day space flight, the crew commander and flight engineer were examined. The following lipid peroxidation parameters were measured in blood serum: concentration of diene conjugates, malonic dialdehyde, Schiff's base, and total antioxidant activity.

**Results:** Lipid peroxidation in both groups of subjects intensified starting on day 230 of hypokinesia with head-down tilt. Concentrations of final products of lipid peroxidation, Schiff bases, remained depressed compared to control values. On days 1 and 7 of recovery, only the concentrations of primary products of lipid peroxidation (diene conjugates) increased, while total antioxidant activity decreased sharply, as is characteristic of reduced physiological resistance and adaptive capacity. This was not accompanied by increased generalized lipid peroxidation, suggesting the possibility of exhaustion of lipid peroxidation substrates in the subjects' bodies. Additional evidence for this was the unaltered concentrations of secondary and final lipid peroxidation products at this time.

After a 1-year space flight a qualitatively different reaction of the lipid peroxidation system was manifest: there were changes in different directions in the levels of all lipid peroxidation products, with an increase in overall antioxidant activity. This suggests, first, the possibility of a compensatory process, and second, the maintenance of lipid peroxidation substrates. Diene conjugates and malonic dialdehyde normalized by day 7 in both cosmonauts, demonstrating the positive course of the recovery.

**Conclusions:** Judging from parameters of the lipid peroxidation system, cosmonauts completing a 365-day space flight were substantially better adapted to its conditions than subjects in an

## **METABOLISM**

experiment involving hypokinesia with head-down tilt. This was manifest in the more rapid stabilization and normalization of lipid peroxidation parameters during the recovery period in space crewmembers.

P1374(30/91) Popova IA.

***Evaluation of metabolic status in humans after exposure to real and simulated weightlessness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 545-547.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Metabolism, Catabolism

Humans, Males, Cosmonauts

Space Flight, Short-Term, Long-Term, Immersion, Hypokinesia With Head-Down Tilt, Graded Exercise Tests

**Abstract:** In the system of comprehensive monitoring of cosmonaut health status, emphasis is placed on biochemical studies of the humoral components of blood. Most frequently the methods of clinical biochemistry are used, and the examinations are performed with cosmonauts in a state of rest.

This work presents a concept of investigation of energy (catabolic) metabolism in response to actual and simulated weightlessness which is based on study of the dynamics of the major energy substrates, intermediate and final metabolites, and activity of the enzymes and hormones that regulate energy metabolism, measured in human blood with subjects at rest and in response to a graded exercise test.

A total of 27 cosmonauts exposed to weightlessness for periods of 8 days to 1 year were studied. A data bank was created and used to compare individual data and for detailed statistical analysis of responses. After space flights, there were significant changes in biochemical parameters in blood characteristic of integrated reactions of energy metabolism: concentrations of glucose, lactic and pyruvic acids, triglycerides, free fatty acids, the activity of several enzymes, and also glucocorticoids, hormones of the thyroid and pancreas glands. As a direct function of flight duration, activity of Krebs cycle enzymes — malate dehydrogenases and isocitrate dehydrogenases — decreased in cosmonauts' blood. Because biochemical studies of metabolic status in cosmonauts during space flight have been very limited in number, information obtained during ground-based flight simulations using the methods of dry immersion, bedrest, and hypokinesia with head-down tilt varying in duration are of major importance. The data obtained under these conditions, with participation of 39 human subjects, confirmed the relationship between changes in biochemical parameters of catabolic metabolism and the effects of simulated flight factors. However, these experiments did not show any effect of the prophylactic measures that were tested, although these measures significantly improved the status of skeletal musculature and physical performance. Graded physical exercise tests revealed the efficacy of the measures utilized, and made it possible to further specify the biochemical parameters essential to characterize that status of energy metabolism in humans exposed to extreme factors.

Thus, work to develop and define a set of biochemical parameters that more accurately reflect the changes in human metabolism led to approaches based on creation of a data bank for evaluating the status of metabolism in cosmonauts during preparation for and participation in

## **METABOLISM**

space flight. The results of the biochemical analyses, pre-, in-, and postflight, must be compared with each other and other physiological data. Such parameters as blood concentrations of glucose, lactic and pyrracemic acids, triglycerides, activity of malonic dehydrogenase, isocitrate dehydrogenase, lactate dehydrogenase, and creatine phosphokinase can play an important role in the comprehensive evaluation of energy metabolism status. The study of venous blood taken during space flight, the use of tests with graded exercise, and the biochemical study of blood significantly deepened our understanding of metabolic status in cosmonauts.

P1394(30/91)\* Bychkov VP, Panferova NYe, Kalandarov S., Korshunova VA, Tret'yakova VA, Pervushkin VI.

***The effect of elevated doses of ultraviolet radiation on certain metabolic parameters in humans.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(50): 46-48; 1990.

[9 references; 4 in English]

Metabolism, Hematology, Body Fluids

Humans

Radiobiology, Ultraviolet Irradiation

**Abstract:** Three experiments were performed with 20 subjects. Minimum skin sensitivity to ultraviolet radiation (minimum erythema dose/MED/) was determined for each subject. In experiment 1 subjects were exposed to an ultraviolet dose of 2 MED (2 subjects), 3 MED (3 subjects), 4 MED (3 subjects). In experiment 2, subjects (3 in each condition) were exposed to doses of 5 and 6 MED, and in the third experiment to doses of 7 and 8 MED (3 subjects each). Each subject underwent two irradiation sessions, with different surface areas exposed. In the first exposure, the skin of the forearm, neck, and upper back (12-15% body surface) was exposed. In the second session, 7 days later, the skin of the back, chest, upper abdomen, arms, and neck was exposed (40-45% body surface). To determine MED the ultraviolet source was located 1.5 m from the surface irradiated. Subjects continued with their normal activities during the period of the experiment. Blood was taken from the subjects' ulnar vein 3 to 5 days before the first session, 24 hours after the first and second session, and 72 hours after the last session. The following parameters were measured in blood: total protein, total lipids, cholesterol, lipoprotein fractions, 11-oxycorticoids, and hematocrit. Venous blood from the finger was used to measure quantity of leukocytes, erythrocytes, hemoglobin, and erythrocyte sedimentation rate (ESR). Total nitrogen and 17-KS were measured in daily urine. In addition, amount of water consumption and daily diuresis were recorded.

Ultraviolet radiation in the doses studied induced redness of the skin, and in doses of 5-8 MED also led to edema in the exposed areas. Diuresis decreased in subjects exposed to doses greater than 4 MED in the first 24 hours after irradiation. Water consumption increased after the second irradiation session for the 7-8 MED dose. Subjects irradiated at 7-8 MED displayed an increase in excretion of nitrogen 72 hours after their second irradiation session. These effects may be attributed to stress, as confirmed by data showing increased blood 11-oxycorticoids after the highest dose of irradiation. Other parameters fluctuated within the limits of the physiological norm. The authors point out that although exposure to elevated doses of ultraviolet affected more than the skin, irradiation was not accompanied by the leukocytosis and decreased ESR characteristic of thermal burns.

Table 1: Diuresis and excretion of total nitrogen

Table 2: Level of 11-corticoids in blood serum and renal excretion of 17-KS

Table 3: Metabolic parameters in subjects

Table 4: Peripheral blood before and after irradiation



## MUSCULOSKELETAL SYSTEM

### PAPERS:

P1354(30/91) Popova IA.

***The modifying effect of weightlessness on repair processes in rats (as indicated by results of biochemical analysis of blood).***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 333.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Musculoskeletal System, Bones, Healing Rate, Blood Parameters

Rats

Space Flight, COSMOS-2044, Tail Suspension

**Abstract:** Many physiological effects of weightlessness in animals manifest themselves in changes in the chemical composition of blood. The main goal of the experiment with rats on biosatellite COSMOS-2044 was to study the modifying effect of actual and simulated weightlessness on repair processes in the healing of a local fracture of the fibula bone. The effect of weightlessness on the course of the repair process may be tracked by comparing biochemical parameters of blood plasma in intact and injured rats exposed to space on a biosatellite, and also those undergoing a ground-based simulation study using "tail suspension."

The results showed that only injured, not intact rats, displayed a depressed concentration of total calcium and protein in blood plasma compared to controls. "Suspended" animals also displayed a decrease in total protein, but not calcium. Neither space flight nor suspension altered concentration of albumen in plasma in either intact or injured rats. Postflight concentrations of cholesterol and triglycerides decreased in blood of the injured rats. The same effect was observed when injured rats were suspended. Two days postflight rats flown on COSMOS-1887 displayed elevated total blood cholesterol and triglycerides. After flight of COSMOS-2044, injured rats failed to display increased concentrations of urea and creatinine in blood, as had been observed in the intact rats and noted by both Soviet and American researchers after flight of COSMOS-1887. In the suspension condition, level of urea, but not creatinine, increased only in the blood of intact rats. As noted after COSMOS-1887, activity of alanine and aspartate amino transferases increased postflight in the blood of intact rats. A smaller increase in activity occurred for alanine aminotransferase in suspended rats. Activity of acid phosphatase increased in intact animals both postflight and in tail suspension. An analogous effect had been observed after flight (18.5 days) on COSMOS-936, but 2 days after the COSMOS-1887 flight, instead of an increase, there was a decrease in activity of acid phosphatase in blood. Alkaline phosphatase activity was significantly elevated in the blood after flight on COSMOS-1887, but was unaltered in both intact and injured rats after flight on COSMOS-2044. The ground-based suspension experiment showed that activity of alkaline phosphatase in blood decreased in intact rats and was unaltered in injured rats.

Thus, the modifying effect of weightlessness on the course of the recovery process in healing of a fracture of the fibula was clearly evident in biochemical parameters of blood plasma: concentrations of calcium, total protein, urea, creatinine, and activity of enzymes such as aspartate aminotransferase and acid phosphatase.

## MUSCULOSKELETAL SYSTEM

P1391(30/91)\* Kuznetsov SL, Stepanov VV.

***Reactions of human skeletal muscle fibers to a 370-day period of hypokinesia with head-down tilt combined with physical exercise.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 34-38; 1990.

[18 references; 6 in English]

Musculoskeletal System, Skeletal Muscles, Muscle Fibers, Gastrocnemius  
Humans, Males  
Hypokinesia With Head-Down Tilt, Physical Exercise

**Abstract:** Material for this study consisted of biopsied samples of the gastrocnemius muscles of 10 healthy males, aged 27 to 44, who had participated in a head-down ( $-8^{\circ}$ ) bedrest study for 370 days. The subjects had been divided into two treatment groups ( $n=5$  each) differing in the amount of physical exercise performed during bedrest. Group A did not exercise during the first 20 days, nor between days 121-140 and days 241-260; the remainder of the time they performed one or two exercise sessions a day of maximal and submaximal intensity. Group B did not exercise for the first 120 days of treatment, and then exercised once a day. Exercise performed by group A was greater in amount and intensity than that performed by group B. Before beginning of treatment and every 60 days during and after treatment a needle biopsy was taken of the gastrocnemius. Biopsied material was frozen and stored in liquid nitrogen and until the end of the hypokinesia treatment. The material was placed in a cryostat and serial sections  $10\text{ }\mu\text{m}$  thick were prepared. Material intended for electron microscopy was fixed and embedded in araldite. Activity of Ca-dependent ATPase myosin was identified in serial sections in an incubation medium with pH of 4.3. Activity of NAD-H-tetrazole reductase, succinate dehydrogenase, and muscle lactate dehydrogenase, along with level of glycogen, RNA, and total protein were also measured. Enzyme activity, levels of glycogen, RNA, and total protein were estimated on the basis of optical density of stained preparations measured on a scanning electron microphotometer. To identify muscle fibers of type I and II, ATPase activity was measured in sections, with type I fibers showing high activity and type II low activity. Fiber size (cross sectional area) was measured using a planimeter. Some of the preparations were stained to identify connective tissue of the endo- and perimysium.

No gross changes were noted in skeletal muscle tissue in any group at any point. Starting early in month 2, isolated fibers underwent changes (of the "moth-eaten") type, attesting to dystrophic processes. Changes in connective tissue were not observed during the first half of treatment. However, starting on day 140, local thickening of endomysium was noted surrounding some fibers (more often in group A). Later, thickening of perimysium was also observed, primarily in group B. On days 300-350 in both groups, but more often in A, local accumulation of fine fibers a factor of 2 to 3 smaller than those surrounding them appeared. No statistically significant changes in quantities of type I fiber were noted in either group.

In group B, 60 days of bedrest led to atrophy of skeletal muscle fibers, manifest in decreased size of fibers of both types, decreased concentrations of total protein and RNA, and inhibition of processes of energy (catabolic) metabolism. Change in activity of mitochondrial SDH in type II fibers reflected the early response of these organelles to hypokinesia. Increased duration of treatment to 120 days in group B led to a tendency for size of type I fibers to increase, while type II fibers normalized. However, SDH activity remained low (sic. Table does not show this, perhaps RNA is meant rather than SDH). As hypokinesia duration increased, decrease in SDH activity was noted in type I fibers as well. Concentrations of glycogen decreased in both types of fibers, especially type II. Electron microscopy revealed significant atrophic changes in the contractile and energy (metabolic?) apparatus of the fibers. The myofibrils of the majority of fibers were shortened, the normal ratios among sarcomere elements were disrupted, and actin and myosin filaments were arranged randomly. Areas of destruction of myofibrils and

## MUSCULOSKELETAL SYSTEM

sarcomeres had clear boundaries, forming zones filled with fine-grained contents. Mitochondria with a homogenized matrix, reduced cristae, and fragmented outer membranes were frequent, especially in the subsarcolemma area. Basal membranes of the vessels of the microcirculatory tract were somewhat thickened, with vessels often seen in a state of collapse?, the increased quantity of collagen between fibers.

With exercise during early stages of bedrest, changes in muscle fibers were less pronounced, dimensions were virtually unchanged, and levels of protein and RNA did not decrease significantly, especially after 120 days. Physical exercise did not prevent a decrease in overall level of metabolism (especially in type I fibers), as shown by decreases in all the enzymes studied. Change in exercise schedule, and increase in amount and intensity of exercise, led to increase of metabolism and further decrease in glycogen. Electron microscopy revealed that in group A subjects on days 6 and 120 of bedrest, the contractile and energy apparatus of muscle fibers were in significantly better condition than in group B subjects.

When physical exercise began after 120 days of bedrest, both types of muscle fibers of group B subjects continued to decrease in size for 60 days and only began to normalize on day 240 of bedrest. A similar phenomenon was observed in group A subjects when exercise was discontinued for 20 days. Start of exercise after 120 days of hypokinesia in group B subjects led to recovery of initial levels of enzyme activity (with the exception of LDH which was elevated, suggesting increased glycolysis). Levels of glycogen returned to normal in type I fibers or were elevated in type II. Further continuation of exercise was accompanied by further decrease in overall metabolism in group B subjects, and was 40-50% baseline on day 370. Analogous but less severe changes occurred in activity of SDH, an indicator of mitochondrial processes. However, on days 180 and 240 of bedrest, LDH (sic. appears to mean SDH), was unaltered.

When exercise was resumed in group A, there was an increase in overall activity of oxidative metabolism, with unaltered SDH activity, somewhat diminished LDH activity, and accumulation of glycogen. Further continuation of exercise was accompanied by decreased activity of enzymes in type I fibers and concentration of glycogen. On day 370 of treatment the least severe changes had occurred in type II fibers.

Electron microscopy revealed that as duration of bedrest increased, atrophic changes worsened in group B subjects and were greater than in group A. Changes in exercise schedule were associated with various shifts in state of fibers, which, however, were not as marked as those due to change from no exercise to exercise.

The authors conclude that exercise during bedrest with head-down tilt partially compensates for induced changes. However, level of these processes, as indicated by RNA levels in muscle fibers, virtually always remain depressed. Incomplete normalization is also demonstrated by the presence of fiber-targets? and increased levels of connective tissue during the later stages of the experiment. A 20-day suspension of exercise almost completely negated the preceding positive effects. Early and intense strength-oriented exercise had greater effects. The fact that the cytoskeleton of the fibers remained relatively intact while actin and myosin filaments were destroyed may be the structural basis for the subsequent recovery of the fibers.

Table 1: Quantity of type I fibers in subjects in groups A and B during various periods of hypokinesia with head-down tilt

## MUSCULOSKELETAL SYSTEM

Table 2: Change in the cross-sectional area of muscle fibers, concentrations of total protein and RNA in subjects in groups A and B at various periods of hypokinesia with head-down tilt (in % of baseline)

Hypokinesia duration, day	Fiber type	Group	Area	Total Protein	RNA
60	I	A	86*	110*	115**
		B	74*	83**	63**
	II	A	87*	100	70**
		B	88*	77***	76*
120	I	A	100	94*	83*
		B	80*	80**	63**
	II	A	144*	90*	72**
		B	100	75**	75*
180	I	A	119*	108*	84*
		B	50**	88**	72**
	II	A	100	100	82*
		B	60*	78**	84*
240	I	A	64**	88*	60***
		B	100	85*	72*
	II	A	71*	75**	61***
		B	100	87*	78*
300	I	A	78*	133*	79**
		B	68**	87**	50***
	II	A	100	100	70**
		B	83*	82*	56***
365	I	A	100	100	88**
		B	53**	65**	55**
	II	A	85*	100	74**
		B	77*	67**	60**

\* -  $p < 0.05$ ; \*\* -  $p < 0.01$ ; \*\*\* -  $p < 0.001$

# MUSCULOSKELETAL SYSTEM

Table 3: Changes in activity of metabolic enzymes and in concentration of glycogen in subjects of groups A and B at various points during hypokinesia with head-down tilt

Hypokinesia duration, day	Fiber type	Group	NADH	SDH	LDH	Glycogen
60	I	A	80**	79**	47**	100
		B	70*	100	100	100
	II	A	87*	100	52**	116*
		B	62**	90*	100	78**
120	I	A	100	100	64**	43***
		B	40**	62**	100	60**
	II	A	100	100	77**	54***
		B	82*	100	68*	40**
180	I	A	120*	100	56**	135**
		B	100	100	133***	100
	II	A	133	90*	64**	188***
		B	100	120**	118*	117*
240	I	A	82**	86**	67*	100
		B	68**	120**	100	150?
	II	A	90*	100	59*	156**
		B	74**	100	100	125*
300	I	A	81*	61***	45**	120*
		B	73**	75***	135*	100
	II	A	85*	50***	58**	136**
		B	55*	77**	100	100
365	I	A	82**	65***	25***	100
		B	48**	82**	100	84**
	II	A	100	84*	33**	100
		B	43**	85*	86*	80**

\* -  $p < 0.05$ ; \*\* -  $p < 0.01$ ; \*\*\* -  $p < 0.001$

## MUSCULOSKELETAL SYSTEM

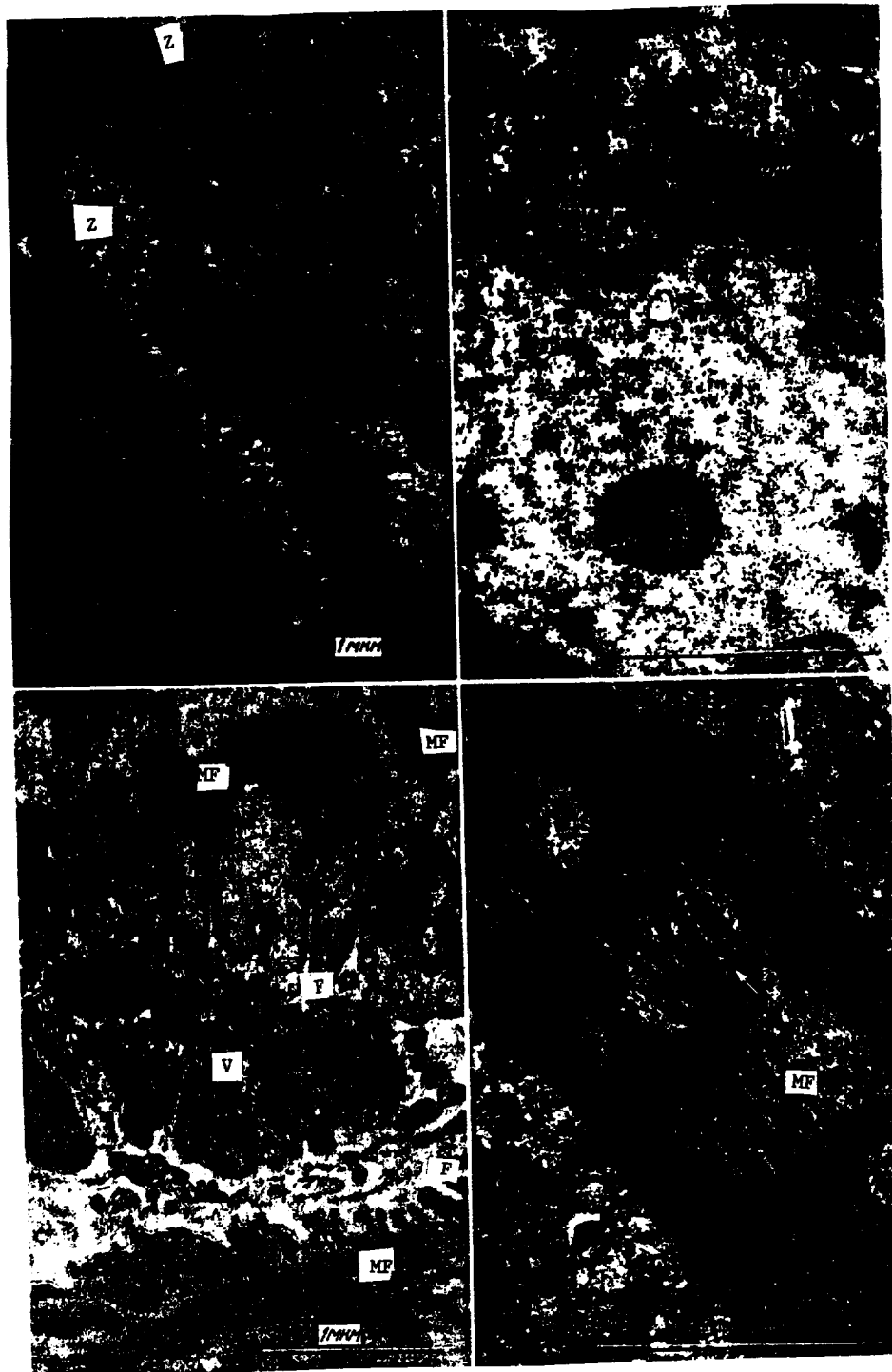


Figure: Areas of the skeletal muscle fibers in groups A (c, d) and B (a, b) at different points in hypokinesia with head-down tilt (stained using Reynolds' method)  
 a - 120 days: zones (Z), destruction of myofibrils (MF), Mag. 26, 700; b - day 365: extensive zones (Z) of myofibril destruction (MF). Mag. 53,000; c - day 365: vessel (V) of the microcirculatory tract in a collapsed state, isolated areas of whole myofibrils (MF); folds (F) of sarcolemma varying in size. Mag. 26,700; d - day 365: the arrow indicates areas of longitudinal splitting of myofibrils.

## MUSCULOSKELETAL SYSTEM

P1392(30/91)\* Pozdnyakov OM, Babakova LL, Demorzhi MS, Il'ina-Kakuyeva Yel.  
***Change in the ultrastructure of striated muscle and neuromuscle synapses of rats in response to a 13-day space flight.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 38-42; 1990.

[9 references; 2 in English]

Musculoskeletal System, Striated Muscle, Soleus, Gastrocnemius, Diaphragm, Neurophysiology,  
Neuromuscle Synapses

Rats

Space Flight, COSMOS-1887

**Abstract:** Subjects in this experiment were a total of 15 Wistar SPF line rats divided into three groups. The first had flown in space for 13 days (spacecraft not specified, but evidently COSMOS-1887); the second was a synchronous control group exposed to all significant environmental factors experienced by the experimental group with the exception of weightlessness and acceleration; and the third was a vivarium control group. Material was taken from various muscles differing in function: the soleus, gastrocnemius, and diaphragm. The soleus muscle is a slow-twitch red antigravity muscle. The gastrocnemius is a fast-twitch, mixed muscle only partially used for maintaining posture. The diaphragm is a continuously functioning? muscle of the mixed type. Although it has special structural properties, it is a typical striated muscle. Two days after spacecraft landing the subjects were sacrificed. Muscle tissue was fixed and embedded in araldite. Ultrafine sections were contrast stained and examined and photographed through an electron microscope. The ultrastructure of muscle fibers was studied in all muscles, as were neuromuscular junctions, intramuscular nerve branches, microvessels, cellular and noncellular elements, and interstitial tissue.

Soleus muscle fibers exposed to weightlessness underwent atrophic/dystrophic changes varying in severity. These were present in virtually all elements of the fibers: myofibrils, nuclei, mitochondria, and the sarcoplasmic reticulum. The myofibrils were frayed and many had begun to disintegrate, leaving cavities filled with homogeneous fine-grained substance and myelin-like inclusions, accumulations of glycogen and lipid droplets. Mitochondria were inhomogeneous in nature with both giant electron-dense mitochondria and small ones with swollen matrices and fragmented cristae. The number of muscle nuclei increased, with migration to the center of the fiber, suggesting denervation. Components of the sarcoplasmic reticulum were broadened and their proliferation led to development of a honeycomb structure in some fibers. These changes suggest the beginning of fiber degeneration. The predominant number of fibers were in a state of "adaptive relaxation." However, there were also signs of activation of reparative processes (increased differentiating satellite cells and nuclear-sarcoplasmic areas), as well as some fragmentation. The state of the microcirculatory tract attested to significant hemodynamic shifts. Arterioles were shortened, capillaries and venules distended and their endotheliocytes electron dense. Pericyte death was observed, with increased quantities of collagen fibers around the microvessels. Disruption of the structure of myelin sheaths was observed in intramuscular nerve branches.

The neuromuscle synapses contained morphological signs of restructuring. They tended to consist of a small number of axon terminals in which the quantity of synaptic vesicle varied. Large ribbon-like mitochondria were localized in the center, and elements of the endoplasmic reticulum were broadened. The postsynaptic membranes formed numerous anastomatizing junctional folds with clearly defined choline-receptive zones. These changes suggest disruption of neurosecretion processes. At the same time, in some of the axonal terminals there were areas of lightened axoplasm, lysis of organelles, and formation of vacuoles around the synaptic membrane. The area of synaptic contact was decreased due to partial or complete disruption of the presynaptic structures. Destruction in the subsynaptic area was not observed. Schwann's

## MUSCULOSKELETAL SYSTEM

cell outgrowths underwent hypertrophy and the number of cytoplasmic organelles increased. When destruction in the axonal terminal was advanced, outgrowths of the Schwann's cell penetrated the synaptic cleft, surrounded and phagocytized the terminals. Axonal growth points in the intercellular space suggested the possibility of recovery of the synapse structure.

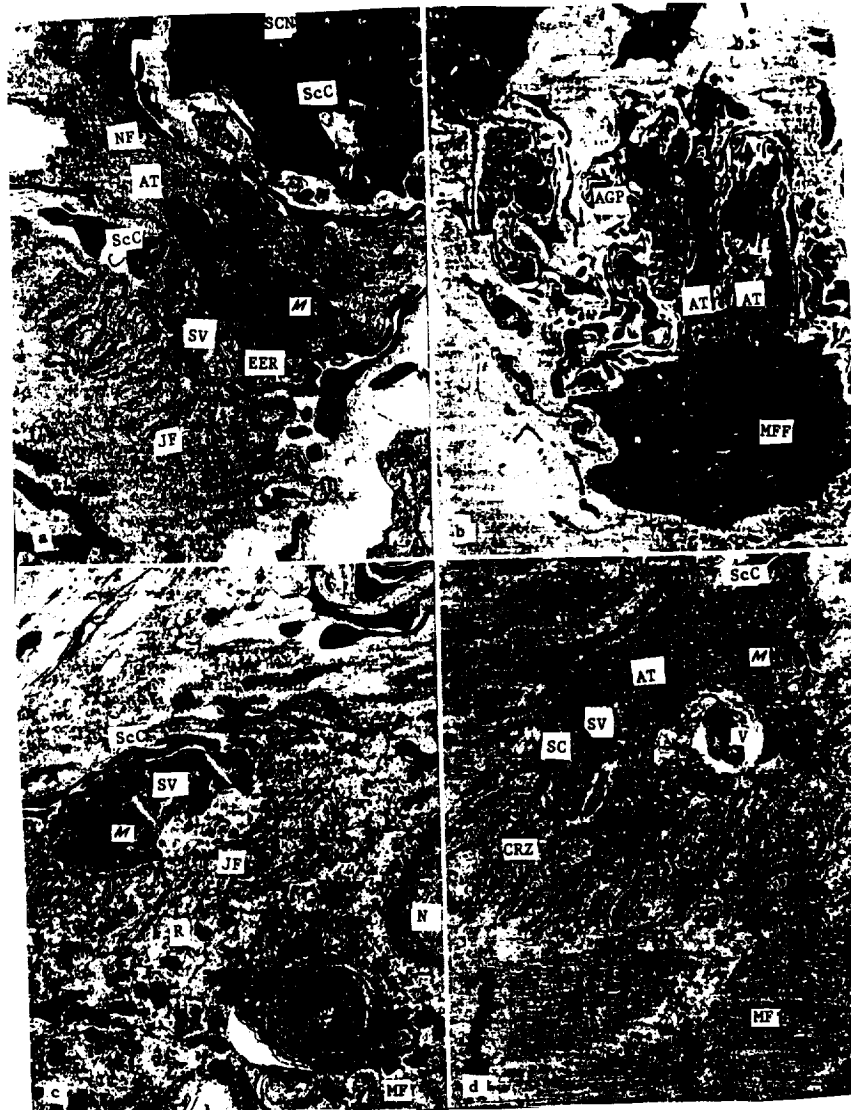
The gastrocnemius muscle structure in flight rats showed the initial stage of atrophic and dystrophic changes. These were, however, not as severe as in the soleus muscle. The restructuring of the synaptic apparatus appeared adaptive and compensatory in nature.

The diaphragm muscle fibers also showed initial signs of atrophy and destructive changes, although these were less severe than in the gastrocnemius. Neuromuscle synapses showed signs of plastic restructuring: widening of the synaptic zone due to increased number of axonal terminals; increased number of synaptic and "complex" vesicles; the postsynaptic membrane had many hypertrophied junctional folds with atypically broad choline receptive zone. These changes attest to activation of the function of the synapses and disruption of their restructuring.

Changes in muscles and synapses of rats in the synchronous group were in the same direction and of the same types as those in animals flown in space, but were significantly less pronounced. There was no disintegration of muscle fibers into fragments, nor signs of cellular macrophage reaction in the soleus muscle.

Interpretation of results was complicated by the fact that material was not studied until 2 days after spacecraft landing. In the soleus muscle landing is associated with hemodynamic disorder leading to interstitial edema and death of a large number of muscle fibers. It is argued that the overall picture favors the reversibility of the changes in this muscle.





ORIGINAL PAGE IS  
OF POOR QUALITY

Figure: Ultrastructure of individual axonal terminals of the neuromuscular junctions of the soleus (a,b), gastrocnemius (c), and diaphragm muscles (d) of rats after a 13-day space flight.

a - axonal terminal of neuromuscular synapse of the soleus (outgrowths of Schwann cells penetrate the synaptic cleft in the area of axonal terminal lysis) Mag. 20,000. b - fragment of muscle fiber with neuromuscular synapse (plastic restructuring of the synapses develops on the basis of active ongoing destructive-regenerative process) Mag. 11,000. c - axonal terminal with signs of "fragmentary degeneration" (agglutination of synaptic vesicles and their lysis: at the base there is a spiral-shaped laminar-tubular structure). Mag. 20,000. d - the axonal terminal shows destructive changes against a background of numerous synaptic vesicles. Hypertrophic junctional fold with atypical discrete-expansion of the choline receptive zone. Mag. 32,000. AT - axonal terminals, SC - synaptic cleft; JF - junctional fold; arrows - presynaptic membrane, double arrow - postsynaptic membrane. SV - synaptic vesicles; V - vacuole; M - mitochondria; EER - elements of the endoplasmic reticulum; N - nucleus of the muscle fiber; MF - myofibrils; NF - neurofilaments; SC - Schwann's cells; SCN - Schwann's cell nuclei; R - ribosomes; AGP - axonal growth point; MFF - muscle fiber fragment; CRZ - choline receptive zone.

## MUSCULOSKELETAL SYSTEM

P1393(30/91)\*Durnova GN, Kaplanskiy AS, Il'ina-Kakuyeva Yel, Sakharova ZF.  
***Histomorphometric analysis of the bones of rats exposed to space on biosatellite COSMOS-1887.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(5): 42-45; 1990.

[17 references; 8 in English]

Musculoskeletal System, Bones, Tibia, Lumbar Vertebrae  
Rats  
Space Flight, COSMOS-1887

**Abstract:** This study investigated the tibia bones and lumbar vertebrae (L4-L6) of five male SPF Wistar line rats after a 13-day space flight on COSMOS-1887, as well as comparable material of the same number of rats in vivarium and synchronous control groups. Rats were sacrificed 2 days after spacecraft landing, and soft tissue removed from the bones. The tibia bones were then cut across with a circular saw and their proximal section (epiphysis and metaphysis) removed and sectioned into two parts in the sagittal plane. Both samples and the diaphysis were fixed. After fixation one-half of the proximal portion was dehydrated and embedded in a JB-4 medium in cold. The other half and the diaphysis were decalcified for 2 weeks. A segment 2 mm in height was removed from the diaphysis at the level of attachment to the fibula, after which the second half of the proximal section and the diaphysis were dehydrated and embedded in plastic. A sharp razor was used to divide the lumbar vertebrae along the intervertebral disks into separate vertebrae and one was embedded in JB-4 medium, and another, after decalcification and dehydration, was embedded in plastic. A hard tissue microtome was used to prepare sections 2-3  $\mu\text{m}$  thick of the nondecalcified tibia and vertebrae, and activity of acid phosphatase was measured, using the nitrogen-combining method. Introduction of 50 mM of sodium tartrate into the incubation medium made it possible to selectively identify activity of the lysosomal isoenzyme of acid phosphatase in osteoclasts, since activity of microsomal acid phosphatase in osteoblasts is suppressed in the presence of a high concentration of sodium tartrate. Decalcified sections of the tibia, 5  $\mu\text{m}$  thick, parallel to the sagittal plane, longitudinal sections of the lumbar vertebrae, and cross sections of the diaphysis were contrast stained.

Histomorphometric analysis of spongy bone tissue used a semiautomatic image analyzer at a magnification of 240 X. For quantitative evaluation of the structure of bone tissue, a formula for computing stereological parameters was used. Quantity of spongy bone was based on measurement of the volume of bone trabeculae, and number and thickness of trabeculae. In addition, distance between trabeculae was measured. The thickness of the cartilaginous growth layer and the width of the primary spongiosa zone were measured. Rate of bone neoformation in the spongiosa was estimated by counting number of osteoblasts in 1  $\text{mm}^3$  of primary spongiosa, and the index of osteoblast activity was determined, since the amount of osteoid in bone trabeculae was so small that quantity could not be determined with an image analyzer. Resorption activity was estimated from counting the number of osteoclasts in the primary and secondary spongiosa showing acid phosphatase activity. Parameters measured were: number of osteoclasts in 1  $\text{mm}^3$  volume of spongiosa, 1  $\text{mm}^3$  volume and 1  $\text{mm}^2$  area of bone trabeculae. An image analyzer was used to determine area of the cortical layer and marrow cavity in cross sections of the diaphysis of the tibia bones.

Results indicated that the amount of bone tissue in the primary and secondary spongiosa decreased postflight. Spongy tissue decreased by 45% in the primary and 32% in the secondary spongiosa compared to the vivarium control. This effect was due to decreases both in number and thickness of bone trabeculae, resulting in an increase in the distance between the remaining trabeculae. Thickness of epiphyseal cartilaginous growth layer and width of the primary

## MUSCULOSKELETAL SYSTEM

spongiosa also decreased in flight rats by 17.5 and 34.6% percent, respectively, compared to the vivarium control. This led to narrowing of the primary spongiosa zone. The total number of osteoblasts and those with high functional activity also decreased in the tibial spongiosa. Number of osteoclasts increased compared to the control group in the trabeculae of the primary spongiosa, but remained the same in the secondary spongiosa. The number of multinucleated osteoclasts and the activity of acid phosphatase was depressed in the primary spongiosa of flight rats. No changes were observed in the width of the cortical layer or the bone marrow cavity.

Rats in the synchronous group displayed decreases in amount of trabecular bone tissue, and in number and width of trabeculae of the tibia. Distance between trabeculae increased only in the primary spongiosa. These changes were less marked than in the flight group. Length of trabeculae of the primary spongiosa decreased. Number and functional activity of osteoblasts also decreased. Numbers of osteoclasts were comparable to the vivarium group, but activity of acid phosphatase was somewhat diminished.

In the lumbar vertebrae of flight rats, there was a decrease in spongiosa, as evidenced by decrease in volume of trabeculae, due mainly to their diminishing in size. Quantity of osteoblasts below the growth layer in the vertebrae decreased by 42% compared to the vivarium control. Other measured parameters were comparable to the control group. No significant changes were observed in the vertebrae of synchronous control rats.

The authors attribute the signs of osteoporosis to the effects of microgravity. However, they consider decrease in acid phosphatase activity in osteoclasts to be due to beginning of adaptation to normal-g (animals were not studied until 2 days after reentry).

Table 1: Results of histomorphometric analysis of the tibial metaphysis

Parameter	Primary spongiosa			Secondary spongiosa		
	Vivar.	Synchron.	Flight	Vivar.	Synchron.	Flight
Growth layer width, $\mu\text{m}$	177.0	190.0	146.0*,***			
Prim. spong. width, $\mu\text{m}$	411.0	399.0	269.0*,***			
Trabec. volume, %	35.4	30.0**	19.5*,***	27.7	28.7	18.7*,***
No. trabec./1 mm	8.5	7.5**	6.1*,***	4.7	5.0	3.8*,**
Trabec. thickness, $\mu\text{m}$	41.0	39.0	31.0*,***	59.0	56.0	47.0*,***
Dist. btwn trabec., $\mu\text{m}$	76.0	96.0**	136.0*,***	157.0	150.0	260.0*,***
Osteoblasts in 1 mm <sup>3</sup>	1134.0	866.0**	925.0*			
Osteoblast index	1.5	1.4	1.3*			
Osteoclast. in 1 mm <sup>3</sup> spong	65.0	70.0	75.5*	32.5	27.4	22.0*,***
Osteoclast in 1 mm <sup>3</sup> trabec.	185.0	241.0	402.5*,***	118.7	99.3	135.9
Osteoclast in 1 mm <sup>2</sup> trabec.	5.0	5.7	7.5*,***	4.2	3.3	3.8

Here and in tables 2, 3: \* significant difference between vivarium and flight groups;  
 \*\* - significant difference between vivarium and synchronous groups,  
 \*\*\*- between flight and synchronous.

Table 2: Results of histomorphometric analysis of the tibial diaphysis

Parameter	Vivarium	Synchronous	Flight
Area of cortical layer, mm <sup>2</sup>	4.57	4.41	4.56
Area of marrow cavity, mm	0.70	0.73	0.74

# MUSCULOSKELETAL SYSTEM

Table 3: Histomorphometric analysis of the lumbar vertebrae

Parameter	Vivarium	Synchronous	Flight
Growth layer width, $\mu\text{m}$	140.0	141.0	143.0
Osteoblasts in $1\text{ mm}^3$	461.0	375.0	268.0*,***
Osteoblast index	1.3	1.2**	1.2*
Trabec. volume, %	27.5	27.6	22.8*,***
No. trabec./1 mm	4.8	5.2	4.7***
Trabec. thickness, $\mu\text{m}$	56.0	54.0	48.0*,***
Dist. btwn trabec., $\mu\text{m}$	162.0	151.0	182.0***
Osteoclast. in $1\text{ mm}^3$ spong.	21.0	15.6**	24.9***
Osteoclast in $1\text{ mm}^3$ trabec.	79.5	57.2	111.9***
Osteoclast in $1\text{ mm}^2$ trabec.	2.9	2.2**	3.5***

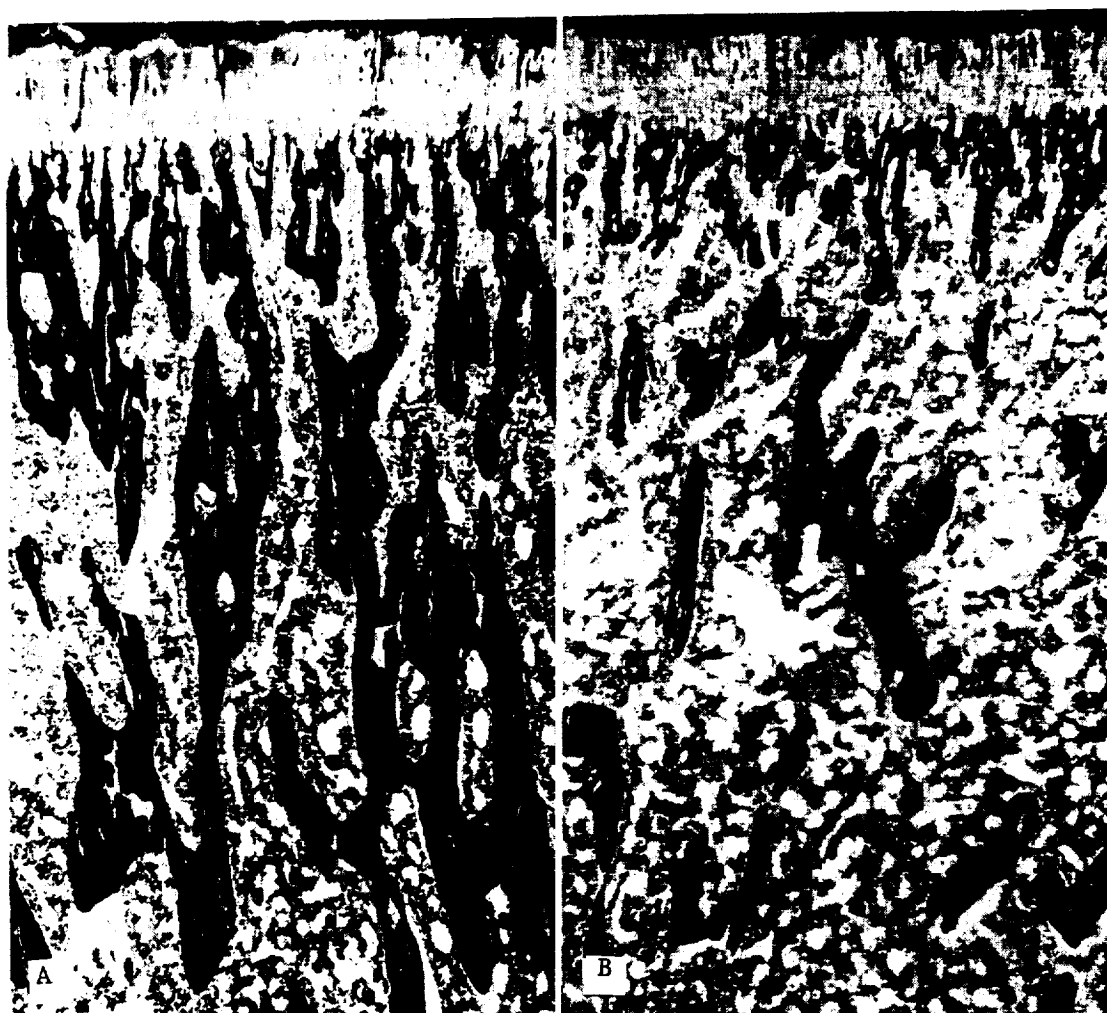


Figure. Osteoporosis of the spongiosa of the proximal metaphysis of tibia bones in rats after a 13-day space flight  
a - control (vivarium), b - flight group. Mag. 2.5, ocular 6.3

ORIGINAL PAGE IS  
OF POOR QUALITY

PAPERS:

P1356(30/91) Shlyk GG, Shirvinskaya MA, Shingur LI, Kolpakova NF, Beradze ZK, Dzhokua AA

***Higher nervous activity in primates flown on biosatellite COSMOS-2044 and in a control ground-based experiment.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 356-357

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Higher Nervous Activity, Psychology, Behavior, Conditioned Responses  
Monkeys, Rhesus Macaques  
Space Flight, COSMOS-2044

Abstract: Study of higher nervous activity in primates exposed to weightlessness and concomitant hypokinesia and isolation is not only significant in itself, but also provides information about the functional status of the animal, which in turn determines the extent and rate of adaptation to new and performance under new conditions.

In this study the major criterion for evaluating higher nervous activity was retention and quality of a conditioned response developed previously. Also, observations of the behavior of the animals during television sessions were made both in weightlessness and in the ground-based control condition. It is essential to note that the rigid restraint system constrained motor acts and led to depression of alertness, drowsiness, apathy, cessation of exploratory activity, and failure to attend to conditioned signals.

During preparations for the flight experiment, complex conditioned responses to light stimuli were developed in two paradigms using juice as a reinforcer. In the first paradigm, the instrumental response was squeezing of a handle. In the second, a movement of the lower limb was reinforced. Each paradigm was presented twice a day (the first at 8:00 and 13:00, the second at 16:00 and 21:00).

In flight, both monkeys (Zhakonya and Zabiakyakya) performed the conditioned responses in full. Data on the animals' behavior as observed through television broadcasts attested that in weightlessness the animals were in fairly good condition, although most often they were drowsy during the first half of the day.

Motor activity in Zhakonya consisted mainly of turning the head, and sometimes of movements of the upper limbs. Zabiakyakya's motor activity was more varied: examination and grooming of the upper limbs, and movements of the fingers. Heart rate recorded before the beginning of the conditioned response performance was generally within the range of the norm. However, in the evening on days 6, 7, 8, and 9 of flight Zhakonya's heart rate increased to 159-165 beats/minute. Zabiakyakya's heart rate increased (to 151-168 beats/minute) on days 3 and 4 of flight. It did not prove possible to juxtapose heart rate and behavioral data for the primates.

## **NEUROPHYSIOLOGY**

In the ground-based control condition, there was a decrease in the level of alertness. There was large variability and increase in mean daily heart rate values.

The data obtained in space flight did not contradict previous research. The primates tolerated weightlessness satisfactorily, without significant disruptions of higher nervous activity.

P1384(13/91)\* Skiba IA, Tkachenko VK, Plyasova-Bakunina IA.

## ***The accommodation function of the eye in cosmonauts.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 14-16; 1990.

[8 references; none in English]

Neurophysiology, Ocular Accommodation, Perception

Humans, Cosmonauts

Space Flight

**Abstract:** The accommodation function of the eye in cosmonauts was studied using "ophthalmo-ergography." Subjects were asked to perform two tasks. In the first they moved various test objects farther and farther until the point where they were no longer clearly seen, and then moved them closer to where they were clearly seen. In the second task they moved the test object increasingly closer to their eyes until it was no longer clearly seen and then farther away until it was clear. (In a third task?) A cobalt glass was placed in front of the subjects eye and the test object was a point light source. In the area of comfortable accommodation the object appears blue in color. As the object moves out of this area it appears blue with a red halo or red with a blue halo. The subject was asked to move the object closer and further away without creating a halo. Three curves were generated on the the ergogram: accommodation for distance, for close vision, and the cobaltogram curve (reflecting the area of comfortable accommodation). The curves were constructed monocularly without cycloplegia. Ergometry was performed for 7-8 minutes and cobaltometry for 1-2 minutes. The ergometric tasks represent a kind of graded visual loading and thus the ergographic curves change as a result of fatigue in the accommodation system. The amplitude of the curves reflects functioning of the visual system. High peaks attest to inaccuracy of visual recognition. Distance from the furthest to the closest boundary of clear vision is expressed in diopters and is indicative of overall accommodation amplitude. The following parameters were analyzed on the basis of the curves: dynamic distance refraction (determined by the distance from the close to the far boundary of the clear vision area at the end of a session); dynamic refraction close-up (determined analogously); total accommodation amplitude distance between far and near boundaries; refraction at rest, analogous to optical gaze fixation in a featureless field and computed from the farthest point of clear vision at the end of the ergometric session; peripheral fatigue — the decrease in functional capacity of the ciliary muscles while functioning — estimated from decrease in accommodation power over the course of 1 minute; and central fatigue, estimated from the difference in ergogram amplitude at the end and beginning of the session. Three types of study were conducted: closest point of clear vision was studied in 3 cosmonauts in space compared with baseline data (60 trials); ergographic measurements were made before and after space flight in 8 cosmonauts during preparation for flight and on days 1 and 3 postflight (432 trials); ergographic studies were conducted of the eyes in a Salyut station mock-up on the ground using 15 healthy subjects (210 trials).

In the first experiment it was found that in only one of the three cosmonauts (and only in his left eye) studied was the closest point of clear vision nearer to the eye in space than on the ground. In the two other cosmonauts this point was further away. Cosmonauts' journals described visual fatigue. The second experiment showed that the overall amplitude of accommodation decreased after space flight, attributable to shift of closest clear vision distance farther from the eye. Parameters of peripheral and central eye fatigue also increased. Visual fatigue was more common after long-term than after short-term flights. Experiment 3, performed during a 3-hour session with healthy subjects on the ground, showed that visual work decreased accommodation amplitude. The authors recommend prophylactic measures to maintain visual performance and prevent visual fatigue in space crewmembers.

Table 1: Changes in accommodation during space flight

## NEUROPHYSIOLOGY

Table 2: Changes in the accommodation function of the eye after space flight from ergographic data (in % of baseline values)

Ergographic parameters	Short-term flight		Long-term flight	
	Day 1 postflight	Day 3 postflight	Day 1 postflight	Day 3 postflight
Dynamic refraction:				
far	171	129	230	138
close	80	91	60	76
Refraction at rest	45	96	133	90
Refraction in cobaltometry	71	47	75	70
Accommodation amplitude	95	98	82	84
Parameter of peripheral fatigue:				
far	100	100	250	50
close	200	200	200	100
Parameter of central fatigue:				
far	160	80	266	100
close	109	91	243	122

Table 3: Changes of certain ergographic parameters in operators working on the Salyut station mock-up (on the ground)



## NEUROPHYSIOLOGY

P1385(30/91)\* Kornilova LN, Bodo G, Tarasov IK, Alekseyev VN (USSR, Hungary).

***Pattern of vestibular reactions and sensory interaction in weightlessness (data from "Optokinez" experiment).***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 16-20; 1990.

[16 references; 8 in English]

Neurophysiology, Vestibulomotor Reactions, Sensory Interactions, Eye Movements, Adaptation  
Humans, Cosmonauts

Space Flight, Optokinetic Stimulation, Head Movements

**Abstract:** The objectives of this experiment performed on cosmonauts were: 1) study of the spontaneous eye movements and the effect of optokinetic stimulation (OKS) on them; 2) evaluation of tracking eye movements; 3) determination of the threshold and superthreshold sensitivity of the eye movement function to graded OKS in various directions; 4) evaluation of vestibulomotor reactions in primarily otolith (shaking of the head in the frontal direction) and canal (rotation of the head around its longitudinal axis) stimulation; 5) study of adaptation of sensory systems to conditions of weightlessness on the basis of oculomotor reactions to vestibular stimulation and OKS. The OKS was displayed on a television screen using a video cassette and included: a single visual stimulus occupying 5° of the visual field (on a screen occupying 20°) moving 20 times in various directions with a frequency of 1 Hz; and black-and-white stripes (each occupying 2°), moving at a rate of from 1 to 20°/sec. in the horizontal, vertical, and diagonal directions (15 seconds in each direction). Vestibular stimulation included: 1) noncontinuous shaking of the head in the frontal plane (from the right shoulder to the level and back with head movement amplitude of about 45°) at a frequency of 1 movement in 1 second over a period of a minute; 2) noncontinuous rotation of the head around the vertical axis (from right to left and back with amplitude of about 45°) and frequency of 1 rotation per second for 1 minute. During the experiment the following parameters were recorded: 1) spontaneous eye movements; 2) tracking movements of the eyes; 3) lower and upper thresholds of optokinetic nystagmus (OKN); 4) eye movements during predominantly otolith stimulation; 5) tracking movements of the eyes, lower and upper thresholds of OKN after active shaking of the head; 6) eye movements during predominantly canal stimulation; 7) tracking eye movements, lower and upper thresholds of OKN after active rotation of the head. Head movements were recorded on a videotape and eye movements using electroculography with onboard apparatus (Aelita). Studies were performed by cosmonaut physician O.Yu Atkov on the crew of a 7-day flight during days 2 and 5 of weightlessness; in one crewmember on a 237-day flight on days 5, 8, 52, 116, and 169, and 200 of flight; and also preflight and on days 2 and 5 after the 7-day flight; and on days 2, 5, 14 and 75 postflight after the 237-day flight.

Preflight there were no signs of vestibular dysfunction. Nystagmus was not recorded when body position shifted in space or the eyes moved to the edge of the field; eyeball position was stable. Correcting microsaccades did not occur when fixation was changed or during tracking. Gain of tracking and tracking phases fell within limits of 0.9-1.1. The lower threshold of OKS was 5-6°/second and the upper 20°/second. The optokinetic reflex and opto-oculomotor? reaction were virtually symmetrical. When the head was nodded as described above, a clear sinusoidal curve for compensatory ocular counterrolling was recorded. When the head was rotated while subjects wore dark glasses a sinusoidal curve was recorded, and when the eyes were open there was a two- or three-peak oculogram. Vestibular stimulation in the form of active head movements increased amplitude of saccades of eye movement response to oculomotor stimuli and led to appearance of corrective saccades.

On day 2 of flight, when eye movements were recorded at rest (open eyes either with or without opaque glasses) spontaneous saccadic and drifting eye movements increased in two subjects and nystagmus occurred in one. Significant changes occurred in the function of visual tracking of

## NEUROPHYSIOLOGY

objects moving in various directions in space flight. The most pronounced changes occurred in tracking of stimuli moving vertically or diagonally. The gain of tracking and the phase ratio decreased significantly in flight, saccade amplitude decreased and lost stability, and additional corrective saccades occurred during the slow tracking phases. Nystagmic reactions occurred in a number of cases. On day 5 of flight, the position of the eyeball stabilized in two cosmonauts. In one cosmonaut, drifting eye movements occurred; on day 169 he also displayed square-wave microsaccadic activity. By day 5 of flight, visual tracking of moving objects was virtually indistinguishable from baseline in all subjects. During the initial period of adaptation to space flight, eye movement response to vestibular stimulation also altered. In two subjects active head movements normalized the eye movement function, and in one completely disorganized it. On day 5 in weightlessness vestibular stimulation had virtually no effect on optokinetic responses. The lower and upper thresholds of the optokinetic stimulation decreased in space (to  $2-3^\circ$  and  $9-10^\circ$ ). This shift persisted throughout the flight. In space both the optokinetic reflex and the opto-oculomotor responses became markedly asymmetrical. The eye movement response to vestibular stimulation was also altered in space. On days 2 and 5, the ocular counterrolling responses during head shaking with closed eyes was somewhat attenuated and became slower, accompanied by low amplitude nystagmus. When the head was shaken with open eyes, on days 2 and 5 of flight, one subject displayed total destabilization of the eye, and the other two high amplitude nystagmic strokes, when rotating the head while wearing opaque glasses, two cosmonauts displayed isolated nystagmic strokes and clear nystagmus when the eyes were open. Thus, although subjects reported no symptoms of space motion sickness, changes were recorded in the system of vestibulo-eye movement interactions, which attested on one hand to increased dynamic sensitivity to visual and vestibular inputs (decreased thresholds of optokinetic and vestibular nystagmus), and on the other hand decreased static vestibular excitability (decrease and disappearance of saccades during tracking of a moving stimulus with stationary head).

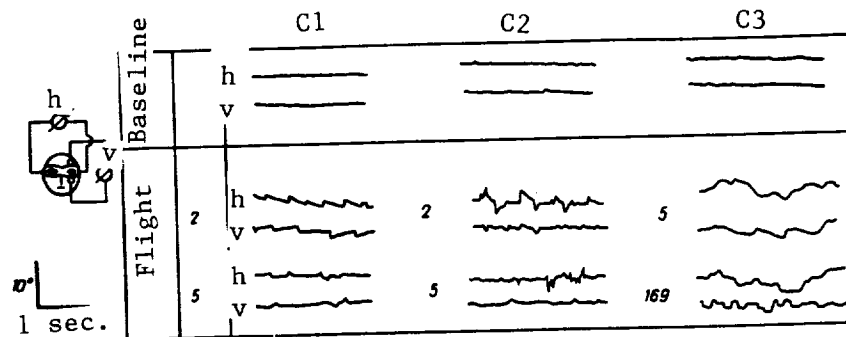


Figure 1: Forms of spontaneous eye movement activity (in dark glasses with open eyes)  
C1, C2, C3 - cosmonauts studied: 2, 5, 169 days of flight; h - horizontal (right nystagmus), v - vertical (upward nystagmus) lead of electroculography

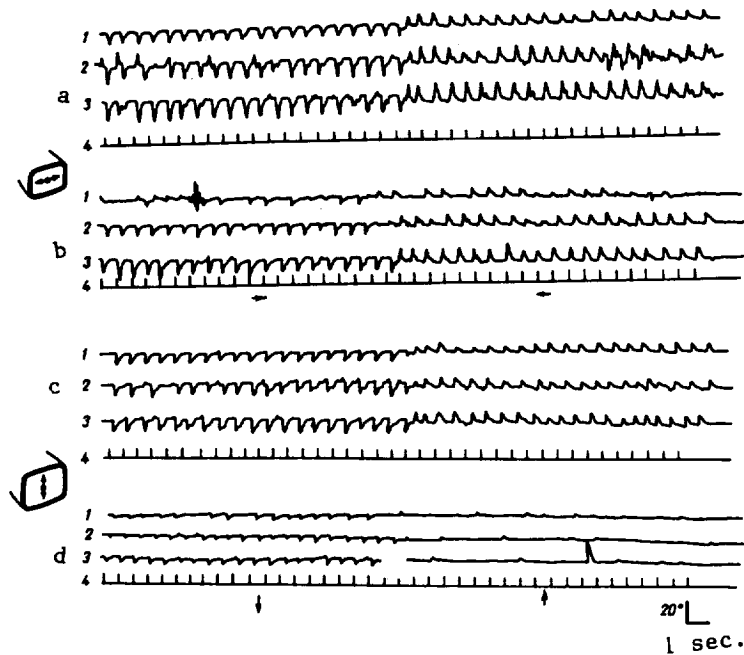


Figure 2: Electro-oculography of tracking function in C-1  
a, b - tracking stimulus moving horizontally; c, d - tracking stimulus moving vertically; a, c - preflight data; b, d - flight data (day 2); 1 - during tracking a visual stimulus before vestibular stimulation 2 - after head shaking; 3 - after head rotation; 4 - stimulus. Arrows - direction of stimulus movement. Calibration: 20°/sec.

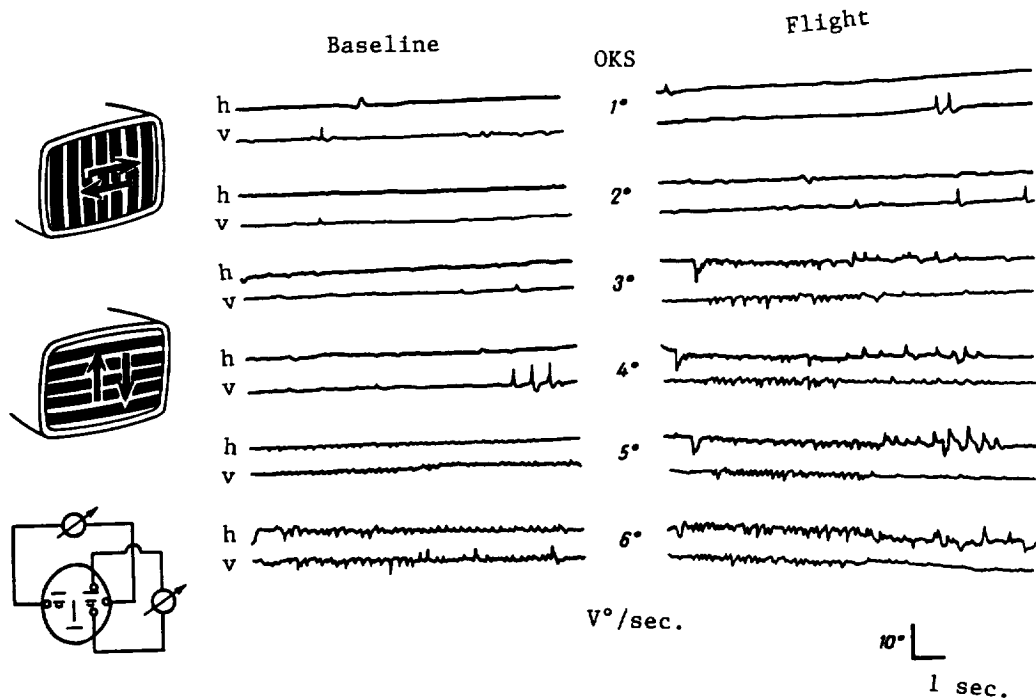
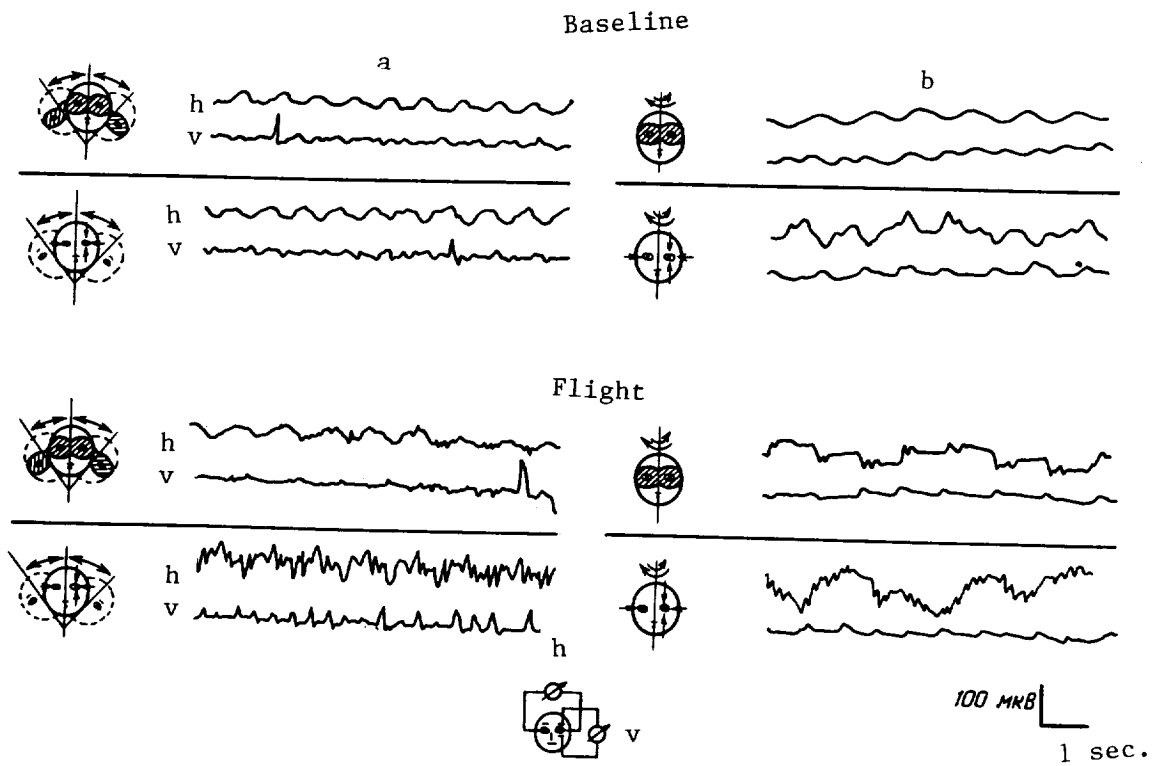


Figure 3: Lower threshold of retinal OKN pre- and inflight (day 2)  
V - rate of OKS (in %/sec.); Here and in figure 4, h - horizontal, v - vertical. Arrows indicate stimulus movement directions. Calibration 10°, 1 sec.



**Figure 4: Nature of EOG during active head movements pre- and inflight (day 2) in C-1**

a - head shaking in the frontal plane; b - head rotation around the longitudinal axis in dark glasses with eyes open and with eyes open and no glasses (gaze not fixed). Calibration: 100  $\mu$ V, 1 second

## NEUROPHYSIOLOGY

P1400(30/91)\* Yasnetsov VV, Pravdivtsev VA, Drozd YuV, Shashkov VS.

***The effect of certain neural mediators and neural modulators on the electrical activity of neurons of the medial vestibular nucleus.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 59-60; 1990.

[7 references; 2 in English]

Neurophysiology, Medial Vestibular Nucleus, Electrical Activity

Cats, Males

Neuromediators, Neuromodulators

**Abstract:** Experiments were performed on seven male cats after administration of curare; respiration was artificially induced. Body temperature and EKG were monitored. The following substances were apparently introduced directly into neurons of the medial vestibular nucleus using techniques of microelectrophoresis: L-aspartate, N-methyl-D-aspartate (NMDA) glycine, norepinephrine, dopamine, serotonin, substance P, and thyroliberin (TRH). Electrical activity of the nerve cells was measured directly. The excitatory amino acid L-aspartate and the selective agonist NMDA increased baseline electrical activity in 100% of the neurons studied. The inhibitory mediator glycine depressed activity in all cells measured. The catecholamines, norepinephrine and dopamine, had approximately the same effect on neurons. A total of 43-45% of the cells responded by increasing electrical activity, 36% by decreasing activity, and there were no changes in 18-20%. Serotonin primarily depressed spontaneous electrical activity of neurons. The regulator peptides, substance P and TRH, generally stimulated electrical activity for 68% and 85% of cells, respectively, but there were also a small number of inhibitory effects.

The authors conclude that the neurons of the medial vestibular nucleus are highly sensitive to the substances investigated. Since many of these substances coexist in the same neurons and presynaptic endings, pharmacological regulation of the process of synaptic transmission using one or a few drugs should prove very difficult.

**Table:** The effects of neuromediators and neuromodulators on the spontaneous activity of the neurons of the vestibular nucleus

P1366(30/91) Nefedova MV.

***The effect of space flight factors on the auditory function of cosmonauts.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;  
Institute of Biomedical Problems, USSR Ministry of Health

Pages: 139-140.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Auditory Function, Perception

Humans, Cosmonauts

Space Flight, Salyut-6, -7, Mir

In the course of medical support of space flights on Salyut-6, -7, and Mir the status of cosmonauts' auditory function was measured and acoustic conditions on board the stations were evaluated. The study of the status of auditory function helped to monitor the reliability of certain conclusions obtained in ground-based simulations of space flight factors. The audiological studies included an otolaryngological history, otoscopy, speech (whisper) understanding, and also threshold and subthreshold audiometry. In accordance with the Audio-1 and Audio-2 programs of international experiments developed by USSR and GDR scientists, the level of sound pressure and the spectral characteristic of noises were measured.

Comparison of results of measurement of sound pressure on Salyut-6 and Mir demonstrated stability of noise parameters throughout a flight. Studies of hearing were conducted on 33 cosmonauts, aged 30 to 54, 30 days preflight, and on days 1, 3, and 60 postflight. Analysis of data from audiometric observations showed that changes in the auditory function in cosmonauts overall were in the same direction. Immediately postflight (days 1-3 of readaptation) all cosmonauts displayed a decrease in auditory sensitivity, especially pronounced for low frequencies, attesting to fatigue of the sound conduction system, associated with cumulative effects of noise. By days 30-60 of readaptation, threshold for low frequency sound had improved and virtually recovered. In the high-frequency portion of the spectrum the changes in hearing were within the range of 0-11 degrees and correlated with flight duration.

While there are individual differences, changes in cosmonaut hearing may be described as involving changes in auditory sensitivity in the area of high frequencies (from 2.0 kHz and higher) for flights of 7 days to 1 year.

Immediately postflight, along with worsening auditory sensitivity, there were decreases in the auditory discomfort threshold. The changes were more extreme in cosmonauts completing long-term flights. Decrease in the threshold of auditory discomfort led to a narrowing of the dynamic range of amplitudes judged uncomfortable.

Thus study of the auditory function of cosmonauts before, during, and after space flights of up to a year in duration showed that the flights lead to the development of auditory fatigue.

P1369(30/91) Sokolov AI, Barmin VA.

***Intersensory interaction in simulation of the effects of the space adaptation syndrome.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 179-180.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Space Adaptation Syndrome, Vestibuloautonomic Symptoms, Adaptation Humans

Perception, Sensory Physiology, Intersensory Interaction, Visual Field Inversion, Horizontal Immersion

**Abstract:** Introduction: The theory that associates the development of space adaptation syndrome (SAS) with conflict among the major sensory systems responsible for orientation in space states that susceptibility to SAS may be due to characteristics of sensory interactions (primarily orientation of the control system to visual, proprioceptive or other modalities), and their capacity to adapt and restructure activity to accord with altered environmental conditions. It is well known that disruptions of interactions of sensory inputs in space can be simulated on the ground. The goal of this research was to study the effects of sensory conflict created by inverting the visual field.

**Methods:** Research was performed on 20 healthy subject aged 23 to 36. The effects of sensory conflict were achieved by having the subjects walk along a certain route (for 20 minutes) while wearing inverting prisms that inverted the field left to right.

The effects of deprivation of musculoskeletal system loading was created by 3 days of immersion hypokinesia. Dependent variables were reported illusions, disrupted motor coordination, degree of vestibular-autonomic disturbance, heart rate, blood pressure, and displaced perception of spatial coordinates (subjective vertical). The inverted visual field was used before and after immersion, and perception of the subjective vertical was studied during unsupported immersion and in the presence of artificial support.

**Results:** The research uncovered a broad spectrum of sensory and motor changes and vestibuloautonomic disturbances. During the first few minutes of exposure to the inverted field, the subjects reported illusions (feeling of motion and displacement of visual surroundings). Motor function was also disrupted in the form of instability while walking, decreases in accuracy of voluntary movements and other phenomena. Severe vestibuloautonomic disturbance (extreme pallor, nausea) developed in 15% of the subjects in the first 10 minutes of field inversion. During field inversion dynamics of the changes observed differed from individual to individual. In 15% of the subjects the effects of field inversion were cumulative and led to pronounced motion sickness symptoms. In the remaining subjects the effects were eliminated during the inversion period, attesting to the development of acute adaptation of sensory systems. The study performed after immersion showed a decrease in illusions in all subjects. At the same time motor disturbances and vestibuloautonomic disturbances occurred in 25% of the subjects, and in three were more pronounced than before immersion. Study of perception of the subjective vertical showed that after immersion the error angle increased in

## NEUROPHYSIOLOGY

all subjects. By day 3 of immersion, the error angle showed a tendency to decrease compared to day 1. Provision of artificial support during immersion led to a decrease in illusory displacement of the subjective vertical, remaining large in only 3 of 20 subjects.

Conclusion: Research showed that the method of horizontal inversion provides considerable information for revealing variability in the mechanism of adaptive changes under conditions of sensory mismatch. This accords with the hypothesis of the role of loss of sensory integration in susceptibility to space motion sickness. The data obtained confirmed the hypothesis that lack of support loading is a factor facilitating development of autonomic reactions of vestibular origin under conditions of microgravity. The results of research with artificial support also attest to the importance of proprioceptive afferentation in the mechanisms of spatial orientation at early stages of exposure to lack of support.



## NEUROPHYSIOLOGY

P1377(30/91) Kornilova LN, Goncharenko AM, Chernobyl'skiy LM (USSR); Grigorova V, Manev A (Bulgaria).

***The tracking function of the eyes in weightlessness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 104.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Visual Tracking, Perception, Sensory Interaction  
Humans, Cosmonauts  
Space Flight

**Abstract:** Introduction: Cosmonauts in flight have displayed specific sensory reactions associated with changes in vestibular stimulation, characteristics of integrative activity of the central nervous system, and the nature of interactions among sensory modalities. This may be reflected in eye-movement reactions tracking visual objects.

**Methodology:** This work studied eye-movement reactions in space on the part of the physician-cosmonaut (241 days) and a payload specialist (10 days). The study was conducted on days 3, 5, and 164 of flight. An oculogram was employed to record eye movements during fixation of a point stimulus and tracking of its linear and circular movements. A personal computer was used to record and process information.

**Results:** On day 3, subjects displayed a decrease in the amplitude of fixation turns along the vertical, a decrease in amplitude and alteration of the form of saccades along the horizontal and vertical, and some worsening in tracking along a circular path. On day 5 of flight, amplitude of vertical upward fixational movements decreased and there was asymmetry in direction of tracking along a circular path at slow speeds. On day 164 of the flight, eye movements in the horizontal direction (fixational movements, saccades, and tracking) were appropriate, movements in the vertical direction were diminished and unstable, and movements along the diagonal were asymmetrical and unstable. Postflight, diagonal tracking was asymmetrical.

**Conclusions:** The data obtained show changes in the tracking function of the eyes in weightlessness, especially during early stages of the flight. Changes in the tracking function may be associated with the specific sensory reactions occurring in weightlessness.

**MONOGRAPH:**

M171(31/91) Antipov BP, Davydov IB, Ushakov IB, Fedorov VP.

Deystvie faktorov kosmicheskogo poleta na tsentral'nyuyu nervnyuyu sistemu: Strukturno-funktsional'nyye aspekty radiomodifitsiruyushchego vliyaniya Действие факторов космического полета на центральную нервную систему: Структурно-функциональные аспекты радиомодифицирующего влияния. [*The Effects of Space Flight Factors on the Central Nervous System: Structural-Functional Aspects of the Radiomodifying Effect*] Number 66 in series Problemy Kosmicheskoy Biologii; Проблемы Космической Биологии [Problems of Space Biology].

Leningrad: Nauka; 1989.

[328 pages; 53 Figures; 36 tables; 727 references]

**KEY WORDS:** Neurophysiology, Central Nervous System, Radiobiology, Radiomodifying Effects, Space-Flight Factors, Radiation, Nonionizing Radiation, Hyperoxia, Hypoxia, Vibration, Combined Effects, Body Fluids, Brain Hydration

**Annotation:** This monograph is devoted to analysis of the complex structural/functional changes in the central nervous system of experimental animals in response to separate and combined exposure to space-flight factors. Changes in various anatomic and physiological structures of the brain are discussed, and their significance for physiological responses to ionizing and nonionizing radiation, hyper- and hypoxia, acceleration, vibration, and certain combinations of these factors are evaluated. Synergy, antagonism, and additivity of the effects of the stressors cited and radiation are established at the level of the central nervous system.

**CONTENTS**

Introduction (5)

**PART I: OVERALL RESEARCH METHODOLOGY**

Chapter 1. Subjects and methods (9)

Morphofunctional methods (9)

Evaluating permeability of the brain-blood barrier and fluid electrolyte status of the brain (13)

Chapter 2. Structural/functional organization of barriers in the brain (as applied to the effects of space-flight factors) (9)

The brain-blood barrier (18)

Interneuronal contacts (19)

Neuron-glial contacts

Nucleo-cytoplasmic and other intracellular barriers (30)

Hydration electrolyte profile of the brain — a reflection of its barriers (33)

Chapter 3. General description of changes in nerve cells of the brain in response to the factors studied (35)

**PART II. SEPARATE EFFECTS OF SPACE-FLIGHT FACTORS**

Chapter 4. Structural/functional changes in the central nervous system in response to ionizing radiation (40)

Neurocytes (42)

Interneuronal contacts (69)

Structural/functional changes in the blood-brain barrier (77)

## NEUROPHYSIOLOGY

Chapter 5. The blood-brain barrier and the hydration-electrolyte profile under exposure to ionizing radiation (83)  
    Permeability of the blood-brain barrier under different conditions of irradiation (84)  
    Level of fluid in brain structures: dehydration, swelling, and edema (97)  
    Sodium-potassium balance in the central nervous system (111)  
    Sodium-potassium pump and the most important parameters of catabolic metabolism in the brain (117 )

Chapter 6. Changes in the brain in response to nonuniform exposure to microwave radiation (123)  
    Conditions of nonuniform irradiation (124)  
    Morphofunctional effects (125)  
    The blood-brain barrier and hydration profile of the brain (139)

Chapter 7. Description of the structural/functional effects in the brain in response to altered atmospheric composition (140)  
    Hypoxia (140)  
    Hyperoxia (142)  
    The blood-brain barrier and hydration electrolyte profile of the brain in exposure to acute hypoxia and hyperoxia (159)

Chapter 8. Some structural/functional changes in the brain in response to dynamic flight factors (167)  
    Vibration (167)  
    Acceleration (179)  
    The blood-brain barrier and hydration-electrolyte profile of the brain under exposure to vibration and acceleration (185)

## PART II: RADIOMODIFYING EFFECTS OF SPACE-FLIGHT FACTORS

Chapter 9. General principles, approaches, and levels of analysis of combined effects (190)

Chapter 10. Combined effects of ionizing radiation and altered atmospheric composition on the brain (197)  
    Manifestations and properties of the oxygen effect for the central nervous system (197)  
    Permeability of the blood-brain barrier (201)  
    Hydration-electrolyte profile of the brain (205)  
    Structural metabolic characteristics of the central nervous system (213)  
    Multilevel study of the modifying effects of change the atmospheric composition using the visual system as an example (230)  
    Summary of the structural functional changes typical of the oxygen effect for the central nervous system (239)  
    Radiomodifying effect of chronic hypoxia and hyperthermia (243)

Chapter 11. Radiomodifying effects of microwaves and other factors (251)  
    Microwaves (251)  
    Vibration (260)  
    Acceleration (277)

Conclusion (286)

References (290)

### Conclusion

The central nervous system (CNS) has long been a focus of specialists in space radiobiology. The reason for this fact is relatively clear. The brain integrates the activity of man, on Earth and in space. The successful performance of a flight mission, to a significant extent, depends on the efficient functioning of the CNS. All areas of space biology and medicine, beginning with cosmonaut selection and ending with psychological support of crewmembers, include issues associated with predicting the resistance of the CNS to extreme factors. Indeed, a new area of research — space neurology — has been born, including (according to Dauntton) the study of neuronal, neurochemical, and behavioral changes in response to space-flight factors encompassing the interactions of the physiological systems that respond to weightlessness.

The effect of radiation on the CNS has been studied by specialists in space biology for a relatively long period of time. However, in most substantive reviews discussion of neurochemical and neurological effects rarely covers the combined effects of space flight factors.

And yet one example of the combined effects of environmental factors — modification of radiation damage to the central nervous system by other factors — is very important for developing space flight standards for radiation exposure. This in turn is one of the most important goals of space biology. Speaking figuratively, the combined effects of factors comprise the ultimate tribunal for judging the adverse effects of ionizing radiation.

This book attempts to demonstrate that even low intensities of other factors (change in the composition of the atmosphere, electromagnetic irradiation, vibration, and acceleration) may have a radiomodifying effect on the severity of structural/functional effects in the CNS.

The use of ionizing radiation to reveal latent changes induced by flight factors is convenient, since, first, the radiation factor can be generated in strictly stipulated doses, and second, a rather large set of structural and functional phenomena have been described in response to irradiation of the brain.

Of course, research on the radiomodifying effects of factors on the CNS is not conducted simply to induce certain abstract phenomena, but the goal is to predict certain possible situations. Thus, in studying the effect of space-flight factors on the CNS, particularly on its structural/functional organization, there are two basic approaches. The first, unifactor approach, is the most traditional — one studies the effect of each factor on various structural/functional parameters. We have attempted to summarize the relatively extensive information in the literature produced by this research approach, as well as our own new data in chapters 4-8. The other, a multifactor approach, involves use of one space-flight factor — radiation — as a kind of loading test. The advantage of this method is that doses of ionizing radiation can be graded with high accuracy, and that as dose increases, more and more new systems begin to respond, including the CNS. Modification of these quantitative functions by other space-flight factors will attest to the need to consider these combinations under conditions where a dangerous situation may arise with regard to radiation. This technique for studying structural/functional effects on the CNS led us to the need to make more extensive use of mathematical methods for planning and analysis of experimental data. Unfortunately, high quality is not always a concomitant of morphological research. The rational use of a multifactor approach in analyzing the structural/metabolic shifts in the CNS is, in our opinion, a rather promising route to take in this area.

Recently, the conception of individual radiosensitivity has been proposed and developed. This approach involves considering individual changes in severity of response to radiation as a reflection of general physiological adaptability to environmental factors. For this reason the

## NEUROPHYSIOLOGY

radioresistance of the CNS serves, to some degree, as a reflection of nonspecific resistance, which has developed in the process of evolution under the influence of various primarily extreme environmental factors. An important role in this process has been played by individual physiological adaptation to harmful stimulation in the form of a stress reaction, mobilizing the protective and recovery systems of the body. We should note that the period of increased tolerance of the CNS may not coincide in time with that of other systems. For example, in adaptation to hypoxia and hyperthermia, the radioresistance of the CNS actually decreased at certain measurement points.

In an expert structural/functional evaluation of the various possible combinations of the radiation factor with other environmental factors, we identified the most reactive systems as the blood-brain barrier and various interneuronal contacts. The opinion was expressed that a fixed CNS state in an organism undergoing exposure to one or more factors may be described by the pattern of concentrations of water and sodium and potassium ions in various areas of the CNS, i.e. hydration-electrolyte profile, which is directly associated with the functions of the blood-brain barrier. For various isolated and combined effects at various times, we have established virtually all forms of pathobiological ionograms. The direction of changes depends on the phase of development of the process. Changes in the brain-blood barrier and the hydration-electrolyte profile of the brain are a universal reaction of brain tissue to the effects of various factors. Of course, under conditions of weightlessness leading to severe changes in the hydration status of the body, these shifts may take on special physiological and behavioral significance. It is also important that the set of effects described in this book were established for three or four species (mice, rats, cats, dogs), which confirms the generality and similarity of many CNS reactions to the separate and combined effects of space-flight factors.

It is very important from our point of view that, within the radiomodifying effect, virtually every factor has both negative and positive aspects. Everything depends on the criteria considered. This is particularly obvious for the most easily gradated nonradiation factors, such as oxygen and hypoxia.

Finishing our discussion of certain general conclusions of research on the radiation tolerance of the CNS under conditions of additional exposure to other space-flight factors, it should be acknowledged that currently it is still impossible to give unambiguous answers to questions about the combined effects studied, as was done previously, for example, on the basis of the criterion of lethality. Each answer to one or another question about the CNS must be taken in a particular context: the magnitude, time parameters, and intervals of exposure to the factors, as well as the criteria of the organism's responses, all must be considered. Thus, the problem of combined effects of factors on the CNS (primarily radiation) is awaiting new cybernetic structural/functional and even psychological approaches.

The authors hope that the present book will complete a kind of circle in the study of the problems of combined physiological effects of space-flight factors. Earlier stages in this research were summarized previously in the ninth and fourteenth volumes of the series "Problems in Space Biology and Medicine." In these monographs issues of reactivity and radio-sensitivity, mainly of the hemopoietic and gastrointestinal system, were discussed. Discussion of the structural/functional changes in the brain in response to the radiomodifying effects seems to us to be a logical and essential continuation of study of the problem of the combined effects of space-flight factors on the body.

## PAPER:

P1379(30/91) Popov IG, Bychkov VP, Korshunova VA.

### ***Vitamin fortification of cosmonaut diet on long-term flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine:

IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Pages: 163-164.

Nutrition, Vitamin Fortification, Flight Rations

Humans, Cosmonauts

Space Flights, Long-Term

**Abstract:** As duration of autonomous space flight increases, crew diets contain a greater component of preserved and prepared foods designed to withstand long storage. This increases the importance of sanitary and hygienic and technological measures directed at maintenance of nutritional content (especially the essential nutrients), as stipulated in our country by the balanced diet formula for healthy individuals (developed by A.A. Pokrovskiy), as well as of fortification of the cosmonauts' diet to compensate for substances partially or completely destroyed inactivated, or rendered unavailable for digestion and assimilation in the preservation process. Our nutritionists have long been concerned with the vitamins present in cosmonauts' flight rations, because of the result of the relative instability of many vitamins during long-term storage and exposure to certain environmental factors, as well as the biological importance of providing humans with the optimal levels of these essential nutrients.

Starting with the first flights of cosmonauts on Vostok spacecraft flight rations have always included multiple vitamin supplements. Recently, on Salyut and Mir, the crew has been taking the Aerovit multivitamin, containing 12 vitamins in doses close to the U.S.S.R. accepted daily requirement.

The results of clinical and biochemical examinations of cosmonauts pre- and postflight support a conclusion that regular use of two Aerovit capsules per day virtually eliminated the development of symptoms of deficiencies in C, B1, B2, B6, P, PP, A, and E. However, it should be noted that on these flights, cosmonauts periodically consumed fresh products, including vitamin-rich vegetable products brought to the station by the cargo ships. For this reason, we have until now been dealing with diets containing multiple sources of vitamins, i.e., products brought from Earth and multiple vitamin capsules.

In view of the future increase in duration and the complete autonomy of manned space flights, the task of fortifying flight rations with vitamins will undoubtedly become more complex. This requires further work on the problem, especially in the following directions: 1) further specification of cosmonauts' need for vitamins at various stages of long-term flight; 2) identification of the spectrum of vitamins and vitamin-like substances requiring identification of mean daily physiological/hygienic requirements; 3) development of reliable ways to fortify rations with vitamins through food products, vitamin pills, and nontraditional food sources obtained on board the spacecraft from the biological life support systems; 4) development of short-cut methods for monitoring vitamin levels in cosmonauts to enable timely use of prophylactic measures against vitamin deficiencies on long-term flights.

PAPER:

P1399(30/91)\* Migdal K.

***Personality traits determining risk taking.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 58-59; 1990.

[6 references; 2 in English]

Psychology, Risk Taking Behavior, Individual Differences

Humans, Males, Females, Mountain Climbers

Personality Traits

Abstract: Groups consisting of 30 mountain climbers and 30 controls (with 5 females in each group) were given personality tests. Groups were matched for sex, education, and professional and social status. Subjects were evaluated on Polish versions of the Sensation Seeking Scale and the State Trait Anxiety Inventory. In general, mountain climbers showed higher sensation seeking than control groups. Mountain climbers were less subject to anxiety as a personality trait, but difference in situational anxiety between groups was not significant.

Table 1: Mean values of personality traits

Table 2: Correlations among personality traits

**MONOGRAPH:**

M166(30/91)Vlasova MM.

Mekhanizmy Opozvaniya Neizvestnogo; Механизмы Оpoznания Неизвестного [*Mechanisms for Recognition of Unfamiliar Stimuli*].

Problemy Kosmicheskoy Biologii Проблемы Космической Биологии Problems in Space Biology Volume 62.

Moscow: Nauka; 1989.

[272 pages]

**KEY WORDS:** Psychology, Recognition, Information Deficit, Neurophysiology, Neurodynamics, Mathematical Modeling

**Annotation:** This monograph is devoted to one of the least well-studied areas of human psychology — how recognition occurs under conditions of insufficient information. The author has spent many years performing experimental research in this area, which has permitted her to formulate and provide a rationale for scientific hypotheses, which, taken as a whole, may qualify as a new direction in the study of psychophysiological mechanisms of recognition of objects based on the principles of higher neurodynamics. The book is intended for psychologists, physiologists, and biologists.

**CONTENTS**

Introduction (5)

Chapter 1. Recognition mechanisms: Problems, theories, hypotheses (9)

1.1 Basic theoretical and experimental trends (9)

1.2 Preliminary neurodynamic hypotheses concerning the nature of mechanisms for recognizing unfamiliar objects (32)

Chapter 2. Principles, models, and methods of research (40)

2.1 A comprehensive technique for studying recognition mechanisms (40)

2.2 The major methodology (44)

2.3 Rationale for the models (46)

2.4 A comprehensive method for studying the internal dynamics of recognition mechanisms (52)

2.4.1 A method for testing local changes in excitability of cortical projection areas (52)

2.4.2 Electroencephalography in the comprehensive methodology for studying internal dynamics (61)

2.4.3 Neurodynamics of the electromyogram of the speech and motor systems (68)

2.5 An experimental computational method for determining direction of gaze with respect to a coordinate system and portion of the object (72)

Chapter 3. Higher neurodynamics in recognition mechanisms (86)

3.1 Associative inhibition as a phase of the recognition process (86)

3.1.1 An experimental model (89)

3.1.2 Areas where physiological inhibition has been observed (90)

3.1.3 Experimental study of the mechanisms of inhibition (92)

3.2 Dynamics of neural processes in the identification of the visual and semantic features of objects (99)

3.2.1 Three phases in the mechanisms of recognition (99)

3.2.2 Neurodynamics of the first phase of mental comparison (with relevance to the mechanisms of unconscious isolation of visual features) (104)



## PSYCHOLOGY

- 3.2.3 Neurodynamics of the phase of associative inhibition (in relation to the mechanisms of simultaneous recognition) (106)
- 3.2.2 Phase changes in excitability in verbal systems of association (in relation to the mechanisms of unconscious isolation of semantic features) (106)
- 3.2.5 Latent period of interaction of semantic association systems with immediate cortical projections (in relation to the mechanisms of the third phase in mental comparison), apperception and recognition (117)
- 3.2.6 The effect of verbal instruction on the dynamics of recognition (129)
- 3.3 The neurodynamic hypothesis of the mechanisms of recognizing unfamiliar objects (12)
- 3.4 Chain reactions of dynamic temporal associations in the mechanisms of recognizing unfamiliar objects (146)
- Chapter 4. The problems of artificial intelligence for performing tasks of recognizing unfamiliar objects (156)
  - 4.1 Search, problems, and hypotheses in development of artificial intelligence (156)
  - 4.2 Experimental testing of hypotheses concerning the primary recognition algorithms (160)
    - 4.2.1 Associative inhibition as a phase of the mental process impeding recognition of new objects (160)
    - 4.2.2 Hypothesized algorithms facilitating attenuation of associative inhibition (an attempt to formalize based on neurodynamic research) (162)
    - 4.2.3 The matching algorithm and the problem of attenuation of associative inhibition (167)
    - 4.2.4 The matching algorithm in the dynamics of fatigue and adaptation to conditions of relative hypodynamia and isolation of varying duration (186)
  - 4.3 A methodology for teaching decision-making in certain recognition tasks based on the matching algorithm (204)
  - 4.4 The efficacy of the method of directed teaching of performance of recognition tasks (209)
  - 4.5 A mathematical model of higher mental processes based on the matching algorithm (218)
  - 4.6 A synthesis of automata for solving logical tasks involving recognition of the unfamiliar (222)
- Conclusion (23)
- References (243)

## PAPERS:

P1357(30/91) Antipov VV, Davydov BI, Tikhonchuk VS, Ushakov IB, Fedorov VP.

***Radiocerebral effects of combined exposure to extreme levels of space flight factors.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine:

IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 362-364.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Brain Status

Dogs, Rats

Radiobiology, Ionizing Radiation, Microwave Radiation, Combined Effects, Hypoxia, Hyperoxia, Vibration, Acceleration, Alcohol Intoxication

Abstract: Animal experiments were used to study brain status under separate and combined exposure to such factors as ionizing radiation, hypoxia, hyperoxia, microwave radiation, vibration, acceleration, and acute alcohol intoxication. The rationale for the dose-time schedules used, and for the methodology and design of the experiment are presented in volume 66 of the series "Problems of Space Biology and Medicine."

Radiomodification effects were studied over the course of 100 minutes after head irradiation of dogs at a dose of 75 Gy. This is the period during which neurological symptoms develop in animals. Morphologically it is marked by the presence of loci of intracellular degeneration, mass destruction of synapses and changes in the structure of the blood-brain barrier with the formation of local zones of edema and wrinkling?[vacuolization?] of nuclei. Signs of compensation were not observed after irradiation of the heads of rats in a dose of 50 Gy (after 100 minutes) when the rate of destructive and compensatory-adaptive processes were in equilibrium or 100 minutes after irradiation of the head of rats at a dose of 10 Gy, when functional stress on the cell ultrastructure was observed. A period of 5 hours after whole-body irradiation of dogs at a dose of 5 Gy corresponded to the end of the period of primary response. The greatest morphological changes were noted in the synapses, swelling of perivascular astrocytes with the beginning of formation of local edema. Oxygen in all instances had only an insignificant effect on the death of the animals, but was associated with earlier and more severe neurological symptoms. Exposure to hypoxia attenuated severity of neurological symptoms compared to irradiation alone. The morphological equivalent of the enhancing effects of hyperoxia was the mass destruction of organoids and the neurocytes. As a result, by the end of day 1 population of neurocytes on a unit area was depressed significantly. Mass destruction of synapses with the formation of myelin-like membrane complexes, and destruction of capillary endothelia were also observed. However, when irradiation was combined with oxygen exposure, there were less severe effects on the perivascular astrocytary pedicles. Edema occurred later and was less severe than after irradiation alone. When radiation was combined with hypoxia, destruction of cells and their ultrastructure was less rapidly. Signs of retardation of synaptic transmission, which under conditions of powerful afferentiation may serve as a protective factor, were observed. At the same time hypoxia fostered more rapid decay of the perivascular astrocytes with formation of broad areas of edema.

## RADIOBIOLOGY

When animals were exposed to small doses of microwave radiation before  $\gamma$ -irradiation of the head in a dose of 50 Gy, there was a clear improvement in the state of synapses and an activation of compensatory-adaptive processes. At the same time the opposite sequence of the factors led to a marked synergism of effects. The compensatory-adaptive processes were completely depressed and degeneration of synapses occurred more frequently.

Radiomodifying effects of dynamic factors depended on the sequence in which they were combined with  $\gamma$ -irradiation. On the whole, when presented before  $\gamma$ -irradiation, both vibration and acceleration led to a better outcome with respect to radiation changes of the brain than irradiation alone. This was true both of synapses and the structure of the brain-blood barrier.

The radiomodifying effects of ethanol in threshold and tranquilizing doses effects were studied in a special series of experiments on rats with irradiation of the head in a dose of 50 Gy. When these factors are presented separately they have similar effects on the state of synapses. Threshold doses of ethanol before or after irradiation failed to have a modifying effect. Tranquilizing doses before irradiation attenuated degeneration of synapses to some extent, but when this dose was given after irradiation it enhanced synaptic changes. Thus, this anthropogenic factor may have a significant modulating effect on physiological resistance to flight factors. The data in the literature concerning oxygen effect confirms the conclusion drawn.

P1359(30/91) Bugrov SA, Tikhonchuk VS, Soldatov SK.

***The problem of radiation safety in space flight under exposure to combined effects of ionizing and non-ionizing radiation.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 368-369.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Radiobiology, Radiation Safety, Space Flight

Rats

Ionizing Radiation, Microwaves, Magnetic Field, Combined Effects, Radioprotectors

**Abstract:** Problems of protecting spacecraft crews from the adverse effects of the environment are extremely urgent, since their solution is closely associated with the problem of cosmonaut life support. The space-flight factors that are potentially dangerous to humans include ionizing radiation, the physiological effects of which may significantly decrease efficiency.

At present, as the power of radar stations and thermonuclear installations increase, microwave radiation has begun to be considered one of the possible active modulators of radiation damage. The problem of the combined effects of ionizing and microwave radiation has been researched more than once by Soviet scientists. However, it is of interest to study the interaction of these factors under conditions of a powerful (to the point of being harmful) electromagnetic field.

The major experiment was conducted on 360 outbred female rats weighting 250-300 g under combined exposure to ionizing and non-ionizing radiation. Some subjects were given the radioprotective drug Mexamine (5-methoxytryptamine hydrochloride, a radioprotective substance close to serotonin in chemical structure and pharmaceutical action), and exposed to lethal doses of electromagnetic radiation.  $\gamma$ -irradiation utilized the "Khixotron" apparatus (0.76 Gy/min) in doses of 4 and 8 Gy followed by irradiation of microwaves of H-polarization with frequency of 2.4 GHz for 1 minute 20 seconds and 3 minutes in an anechoic chamber. Specific absorbed dose was  $105 \pm 3.28$  W/kg. Survival was evaluated on day 1 (death from microwave irradiation) and before day 30 (radiation death). Mexamine hydrochloride was administered in a dose of 15 mg/kg intraperitoneally 20 minutes before microwave irradiation.

It was established that the interaction of ionizing radiation and microwave irradiation at the level of the whole organism is synergistic, due to the damage done by microwave radiation to the central nervous system. The effect of microwaves increased death rate during the first day by 35-55%. The regression equation of survival under exposure to combined irradiation derived through factor analysis was:  $Y = 52.7 + 24 X_1 + 17 X_2 - 11 X_1 X_2$ . Mexamine had a protective effect with otherwise lethal doses of whole-body irradiation with microwaves. Resistance to the effects of microwaves increased by 40%. The mechanism of the protective effect is believed by the authors to be associated with the desensitization phase of preparation of the indol series.

The results obtained support a conclusion that in space flight, the problem of radiation safety under exposure to combined harmful doses or irradiation due primarily to central nervous system damage must be solved with a multifactor approach.

## RADIOBIOLOGY

P1381(30/91) Vasilev T, Pironkov A, Karadzhov A, Traykov A (Bulgaria); Akatov YuA, Burkavich AR, Popov VI, Portman AI (USSR).

***Radiation physics results of the Soviet-Bulgarian "Doza-B" experiment on space station Mir.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 369-370.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Radiobiology, Dosimetry, Doza-B, Equipment and Instrumentation, Condensation Ionization Chamber, Thermoluminescent Dosimeter  
Humans, Cosmonauts  
Space Flight, Mir

**Abstract:** The goal of the Doza-B experiment was to study the radiation conditions on board space station Mir. The experiment was based on development of an ionization dosimeter — the condensation-ionization chamber KIK/CIC/-2. Along with the chambers, the experiment utilized thermoluminescent dosimeters (TLDs) of various types. The CIC-2 and TLDs were placed at various points within Mir so that comprehensive information could be obtained about radiation conditions by independent methods.

The CIC-2 dosimeter consisted of an electric capacitor, forming a tissue equivalent wall of the ionization chamber and its central electrode. Before exposure the CIC-2 was charged by a station on the ground. The difference between the initial and residual voltage on the CIC-2 after irradiation is a measure of the absorbed dose. The total measurement error of dose measured using the CIC-2 is no greater than  $\pm 15\%$ . A set of standard TLDs of various types were selected so that in addition to recording of dose, the presence of thermal neutrons and soft photonic radiation would be detected.

As a result of the experiment, a map of the dose field on space station Mir was derived. Dose differential between various points on the station was 1.6. The mean value of dose rate was equal to 30 mrad/day. The readings of CIC-2 and TLD at various points coincided within the bounds of measurement error of  $\pm 10\%$ .

The Doza-B experiment revealed the high performance of the CIC-2 condensation ionizing chamber, which was used for the first time in space. It was concluded that it is possible to use it for the study of radiation conditions as well as for personal dosimetry.

The correspondence of readings of the TLD-600 and TLD-700, which differ in their sensitivity to thermal neutrons by a factor of approximately 400, suggests the virtual absence of thermal neutrons in the dose field. The virtually identical readings of the TLD-200 (effective atomic number 16.3) and the TLD-600, and -700 (effective atomic number of 8.3) attest to the virtual absence of photon radiation with energy of 0.2 MeV as well.

P1360(30/91) Kovalev YeYe, Vikhrov AI, Petrov VM, Ryshov NI, Sakovich VA.

***The problem of ensuring radiation safety on the manned Mars mission.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 379-380

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Radiobiology, Radiation Safety

Theoretical Article

Space Flight, Mars Mission

**Abstract:** Current thinking is that a Mars mission of 2-3 years could involve sublethal doses of irradiation. Decrease in radiation exposure to an acceptable level may be provided by a special radiation safety system. The creation of such a system is associated with the following factors:

— the necessity of implementing new approaches to the evaluation of radiation conditions and the development of models of the sources of cosmic radiation for flights outside of the Earth's magnetosphere, radiation conditions near and on the surface of Mars, the presence of nuclear sources of radiation on board the spacecraft, and the large number of EVAs the cosmonauts will have to perform with only scanty protection;

— the need to provide an empirical rationale for and develop biological criteria and standards of radiation safety as components of overall safety. It is essential that we develop new socially significant radiobiological criteria of work capacity and operator performance that take into account the spatial and temporal inhomogeneity of irradiation, the specific characteristics of the effects of hadrons on biological structures, the combined effects of radiation and other adverse flight factors, and the issue of individual differences in radiation sensitivity, etc.;

— the need to develop methods of radiation protection for the conditions of the manned Mars spacecraft complex, including issues of a radiation shelter, local protection for EVAs, and optimal protection that allows for nuclear power facilities on board;

— the need to design and construct stand-alone on-board systems of radiation monitoring and prediction that make provision for EVAs, and also a ground-based technical center for operational control of radiation safety;

— the need to perform a series of experiments in space to study radiation conditions, combined effects of radiation and other flight factors on biological systems, and to continue to improve on-board devices and components of the radiation safety system;

— the need to develop a ground-based specialized complex that will produce all types of radiation in the most significant energy region under standardized conditions.

The performance of all the above tasks will make it possible to develop a scientific rationale for a set of engineering and medical methods, devices and measures for use at all stages of design and construction of the spacecraft and performance of the flight, directed at supporting the radiation safety of the crew of the Mars mission.

P1361(30/91) Kovalev YeYe, Vikhrov AI, Ryzhov NI, Sakovich VA.

***Radiobiological aspects of support of radiation safety on flight to Mars.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 380-81.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Radiobiology, Radiation Safety

Theoretical Article

Space Flight, Mars Mission

**Abstract:** Aside from engineering and design measures directed at decreasing the level of radiation exposure, especially during long-term flights, it is essential to solve a whole set of radiobiological problems related to the effects of cosmic and on-board sources of radiation on flight crews. These problems include estimating the modulating effects of nonradiation factors (weightlessness, acceleration of significant magnitude or duration, vibration, altered atmospheric composition, and others) on adverse radiation effects. When the combined effects of radiation and other flight factors are studied, special emphasis must be given to selection and rationale of such socially significant criteria for evaluating radiation effects as work capacity, operator performance, and remote somatic and genetic effects of irradiation. These criteria must include the set of issues associated with psychophysiological status, behavioral reactions, interpersonal relations between cosmonauts, and their resistance to additional psychological stressors.

The effects of irradiation will be characterized by temporal and spatial inhomogeneity, which requires special treatment using pharmacochemical means to decrease the radiation effect. Particular attention must be devoted to the biological consequence of the track structure of heavy charged particles, which may induce effects that are very improbable on Earth and thus have not been studied adequately. In connection with the inevitability of significant radiation effects on long-term flights, it will be necessary to develop methods and means for defining the individual sensitivity of cosmonauts. The results of the research will form the basis for a standard of radiation safety for the Mars mission.

P1395(30/91)\* Lobacheva GV, Galaktionova GV.

***Effects of exposure of the eyes to elevated doses of ultraviolet radiation on the eyes and behavior of rats.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(5): 48-51; 1990.

[21 references; 6 in English]

Psychology, Behavior, Sensory Physiology, Eyes

Rats

Radiobiology, Radiation, Ultraviolet

**Abstract:** This study investigated the possibility of an association between the severity and duration of ultraviolet keratoconjunctivitis (UVKC) and central nervous system effects of ultraviolet radiation. Male Wistar rats were exposed to ultraviolet radiation in the range of 290-310 nm with a maximum of 302 nm in one of seven doses ranging from 0.6 to 10. kJ/m<sup>2</sup>. There were between 4 and 10 animals in each group. Parameters used to indicate condition of the eyes included: 1) presence of a discharge; 2) edema and reddening of the eyelids; 3) bloodshot eyes; 4) edema of the cornea identified using a 1% fluorescent solution; 5) clouding of the cornea characteristic of the initial period of the reaction; 6) and development after 7 days of irreversible changes in the form of "clouds" and cataracts. The first three symptoms were considered signs of conjunctivitis, the remainder signs of keratitis. Each symptom was measured in each subject and a mean value determined for each of the UV-radiation doses. Animals were given an ophthalmological examination 3, 6, and 24 hours after irradiation and then every day until disappearance of reversible symptoms and until day 60 if there were irreversible corneal changes. Behavior of the animals was studied in an open field situation, with 15 irradiated and 15 control animals. Parameters measured during a 5-minute test period included motor activity, orienting reaction, and the burrowing reaction. Emotional activity was estimated on the basis of grooming behavior and number of defecations. The experiments lasted from 14 to 70 days, depending on dose of ultraviolet irradiation. A total of 150 subjects were employed.

Severity and persistence of eye symptoms increased with dose of irradiation. For animals irradiated at the highest dose of 10 kJ/mm<sup>2</sup> the acute period of development of ophthalmological symptoms corresponded to increased motor activity and emotional responses. Orienting and exploratory responses were depressed throughout. At other doses of radiation other behavioral change dynamics were observed 70 days after irradiation. The authors conclude that the period during which stable corneal clouding develops corresponds to a period during which inhibitory processes dominated the central nervous system, which they attribute to partial visual sensory deprivation and adaptive restructuring of the nervous system.

Table: Development of symptoms of ultraviolet keratoconjunctivitis

Figure 1: Dynamics of behavioral reactions of rats in an open field test after exposure of their eyes to ultraviolet radiation in a dose of 10 kJ/m<sup>2</sup>

Figure 2: Dynamics of extinction of horizontal motor activity in rats in an open field during a 5-minute session 1, 7, 14, and 35 days after exposure of eyes to ultraviolet irradiation



## SPACE BIOLOGY AND MEDICINE

### PAPERS:

P1382 (30/91)\* Grigor'yev AI, Bugrov SA, Bogomolov VV, Yegorov AD, Kozlovskaya IB, Pestov ID, Tarasov IK.

***Review of the major medical results of the 1-year flight on space station "Mir."***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

1990(5): 3-10; 1990.

[No references]

Space Biology and Medicine, Habitability and Environment Effects, Microbiology, Automicroflora, Radiobiology, Radiation Conditions, Nutrition, Cosmonaut Diet, Work-Rest Schedule, Neurophysiology, Space Motion Sickness, Psychology, Cardiovascular System, Neurophysiology, Motor Control, Musculoskeletal System, Bone Tissue, Muscle Strength, Metabolism, Carbohydrate Metabolism, Lipid Metabolism, Hematology, Erythrocyte Metabolism, Protein-Nitrogen Metabolism, Body Fluids, Fluid Electrolyte Metabolism, Endocrinology, Immunology

Humans, Cosmonauts

Space Flight, Mir, 1-Year Flight, Prophylactic Countermeasures, Physical Exercise, LBNP

Abstract: A 1-year flight was completed on the "Mir-Soyuz-TM-Kvant-Progress" complex between December 21, 1987, and December 21, 1988. Cosmonauts on this flight were the commander (C-1) V.V. Titov, and the flight engineer (C-2) M.Kh. Manarov. During their flight the prime crew was visited by three international visiting crews (Soviet-Bulgarian, Soviet-Afghan, and Soviet-French), received five cargo vehicles, and performed three EVAs with total duration of 13 hours 47 minutes. Medical support during the flight included monitoring of the environmental and radiation monitoring; monitoring of the crew's health; implementation of the program of prophylactic measures; monitoring and adjustment of the work-rest schedule; and performance of biomedical studies in- and postflight.

### GENERAL DESCRIPTION OF FLIGHT CONDITIONS

Studies showed that habitability conditions during the flight were acceptable and did not differ from those during the tenure of previous Mir crews. The composition, temperature, and humidity of the atmosphere generally remained within the established norms, close to terrestrial conditions. Occasional increases in overall and partial oxygen pressure were associated with scheduled operations such as docking and EVAs. Isolated instances where partial CO<sub>2</sub> pressure exceeded 5-6 mm Hg were due to intense physical exercise or certain technological experiments.

The atmosphere was found to contain acceptable quantities of organic substances attributable to volatile human metabolites and emission from nonmetallic materials. The atmosphere, interior surfaces, and equipment of the station were found to contain representatives of human automicroflora. On the whole, the status of the station was considered good. Intense preflight preparations were found to be associated with dysbiotic shifts in intestinal microflora, which were corrected by administration of bifidum bacterine. Postflight skin microflora was considered satisfactory. The flight was not associated with increases in dysbiosis; on the contrary, range of sensitivity to antibiotics increased, level of bifidoflora increased, and the ratio of bifidobacteria and intestinal bacilli normalized, while level of lactoflora was maintained. These highly satisfactory conditions are attributed to the countermeasures taken.

Throughout the flight, radiation conditions were quiet. Total dose of radiation was 12.2-14.0 rem, or 7.6-8.7 rad.

## SPACE BIOLOGY AND MEDICINE

The cosmonauts' diet, as during the previous expedition, consisted of freeze-dried (65%) and canned products with mean daily caloric intake of 3000.

The work-rest schedule was planned to follow a 24-hour cycle with work time of 8.5 hours and sleep of 8-9 hours with 2 days off per week. During the flight there were 14 instances where the sleep period was shifted by 4.5-5 hours in association with docking operations, and EVAs. The cosmonauts reported that it was easier to tolerate clockwise shifts than counterclockwise shifts.

Prophylactic measures used on the flight included two daily sessions of exercise on the bicycle ergometer and multipurpose treadmill, using a set of expanders and wearing loading suits (for no less than 8 hours per day). During the final stage of the flight, a conditioning cycle involved LBNP with decompression from -10 to -45 mm Hg. On the last day of the flight, cosmonauts ingested fluid-salt supplements and wore anti-g suits during descent and the early postflight period. The suit used was the "Karkas" bladderless suit.

Throughout the flight the cosmonauts maintained good health and high job performance levels. Graded tests on the treadmill showed that both cosmonauts maintained preflight conditioning, with a tendency for conditioning to improve toward the end of the flight.

### RESULTS OF INFLIGHT STUDIES

#### General Description of Cosmonaut State and Anthropometric Studies

**Inflight observations.** After onset of weightlessness both cosmonauts developed moderate facial edema and nasalization of their voices. These conditions persisted during the first day of flight and had virtually no effect on performance. After onset of weightlessness, one cosmonaut developed the illusion of being upside down. Throughout the first 3 days of flight, head movements and looking out the window produced in this same individual sensations of discomfort typical of the initial stages of motion sickness. During certain periods, both cosmonauts noted fatigue at the end of the work day, which was relieved by a night's sleep. There were scattered reports of difficulty falling asleep and awakening during the "night." After EVAs, cosmonauts noted sensations of pain and muscular fatigue in the arms.

**General state postflight.** After landing, crewmembers were extricated from the descent module by rescue personnel. At the touch-down site and during evacuation, both crewmembers remained relatively active. They were capable of independent action and could walk for short distances, although displaying some unsteadiness of gait. Their pulse was labile during stand and exercise tests.

At the touch-down site, both cosmonauts complained of dizziness when they changed the position of their heads, sensations of increased weight of themselves and external objects, and thirst. No symptoms of vestibuloautonomic discomfort were noted. In the medical tent the state of both cosmonauts was rated satisfactory. During evacuation to the intermediate airport, both cosmonauts traveled in horizontal position. However, they entered and left the aircraft under their own power with support from their escorts. During transport in the aircraft to the Cosmonaut Training Center, both cosmonauts displayed pallor, which increased and was accompanied by perspiration in a vertical position. Hemodynamic parameters were labile.

Throughout the first 2 days after reentry, the general state of both cosmonauts was satisfactory. One, as during flight, developed an illusion of pitch and roll and symptoms of vestibuloautonomic discomfort, especially pronounced when he moved his head in a supine position. This somewhat delayed development of vestibular dysfunction could have resulted from excessive activity

## SPACE BIOLOGY AND MEDICINE

during the first few hours after landing, during which on his own initiative he rotated his head in the interests of "vestibular conditioning." Subsequently the state of both cosmonauts was rated "good."

**Psychological status.** Specialists stated that both cosmonauts developed symptoms of asthenization, varying in severity at different portions of the flight. During the first 1.5 months of the flight crewmembers reported fatigue at the end of the day and sleep disruptions. These were considered natural consequences of adaptation to the new conditions of life and work. During month 2, both crewmembers complained of headache at times, diagnosed as a symptom of autonomic vascular dystonia, not requiring correction. During month 4, cosmonauts reported feeling well. Subsequently there were episodes of difficulty falling asleep and rapid alternation of moods (maximally pronounced during months 8-9, after 2 EVAs, and visits by two international crews). Provision of additional days off in month 9 of flight appeared to curtail these phenomena. Some symptoms of asthenization also occurred in the last 1.5 months of flight, during collaboration with the French-Soviet crew. Postflight observations included emotional lability, instability, and distractibility.

**Anthropometric studies.** Changes in body weight in the two crewmembers were in different directions. One gained 2.1 kg over the flight and the other lost 3.3 kg. These fluctuations were considered within characteristic limits. In both cosmonauts, changes from baseline body weight decreased over the early postflight period. Calf volume decreased steadily over the flight and by the end of the flight was 20% below baseline in both cosmonauts. Calf perimeter decreased postflight (by -3 and -1.5 cm on day 1 and by -4 and -2 cm on day 4). This decrease was still evident on day 16 postflight. Perimeters of the upper and lower arm remained unaltered.

### Study of the Cardiovascular System

**Bioelectric activity of the myocardium.** During the flight, both cosmonauts displayed decreased T wave amplitude compared to baseline. On the day of reentry, both crewmembers manifested diffuse decrease in T-wave amplitude and increase in the ratio of QRS to T wave amplitudes, with increased heart rate. Normalization of T wave and QRS/T ratio was complete on days 2-4 postflight. On days 0 and 1 postflight, Holter monitoring revealed significant heart rate lability with fluctuations of from 74 to 128 beats/minute in one crewmember and from 70 to 178 in the other. C-1 recorded 15 isolated right ventricular monotonic extrasystoles, and C-2 recorded 12 isolated left ventricular monotonic extrasystoles.

**Hemodynamics at rest.** C-1's inflight resting heart rate was 56-71 beats per minute, corresponding generally to preflight fluctuations (55-68), with the exception of months 2 and 3 of flight when there were episodes of 15-20% increases in heart rate from the preflight mean (62 beats/minute). In C-2 inflight resting heart rate increased from 56-64 beats/minute (mean of 60) to 63-79 per minute.

C-1's cardiac stroke volume and output remained below mean preflight levels by 13 and 10%, respectively, throughout the flight. In C-2 stroke volume was either 13-21% below baseline or equal to baseline. Cardiac output was generally elevated (by a mean of 15% over baseline). Specific peripheral resistance was elevated by 8-24% in C-1 and decreased by 7-21% in C-2.

Systemic blood pressure fluctuated within narrow limits in both cosmonauts during flight. Regional hemodynamics, studied using impedance plethysmography, were characterized by increase in parameters of pulsed blood filling of the three vascular basins of the head and increased tonus of the large vessels. Vascular reactions primarily involved decreased tonus of precapillary arterioles and postcapillary venules in the basin of the right internal carotid artery (in C-1) and vertebrobasilar system. They also involved the appearance of marked venous waves on the impedance plethysmogram, a sign of impeded outflow of blood from the head.

## SPACE BIOLOGY AND MEDICINE

In the basin of the internal left carotid artery, tonus of small vessels generally did not differ from preflight, attesting to a normotonic state. During the flight interhemispheric asymmetry of vascular tonus developed, as during previous flights. At the same time there were indications of increased blood filling of the lungs and liver.

Echocardiography postflight revealed decreased cardiac ejection, hyperkinesia of the interventricular septum, and moderate enlargement of the anteroposterior dimension of the right ventricle in both cosmonauts. Parameters of myocardial contractility remained within the limits of the physiological norms. All echocardiographic parameters had normalized by day 5 postflight.

**Ultrasound studies of visceral organs** were performed on day 285 of flight and revealed increase in the anteroposterior dimension of the liver and moderate increase in blood filling of the lungs. Postflight both cosmonauts displayed increased dimensions of the liver and pancreas, in the height and thickness of the kidneys and spleen, increased blood filling of the lungs in the area of the lower lobes and in the vascular system — an increase in the cross section of the aorta, the upper mesenteric artery, the inferior vena cava, portal, and splenic veins. The pancreas of one cosmonaut also displayed signs of edema. Severity of changes in visceral organs had decreased sharply by day 15 of the postflight period. The changes noted in viscera included increased filling of the capacitance vessels and blood pooling caused by fluid redistribution. Blood pooling in the visceral organs, particularly the liver, spleen, and lungs, may be considered an adaptive reaction limiting entry of blood into the cardiopulmonary area and thus preventing the development of hypertension in pulmonary circulation.

**Graded physical exercise test on the bicycle ergometer.** Both cosmonauts responded to this test inflight with greater than baseline increases in heart rate and in C-2 [sic., on the basis of conflicting statements in this paper and elsewhere, we have concluded that "C-1" is meant here] a decrease in stroke volume, which had increased preflight. In response to the test C-1's cardiac output decreased while C-2's increased. Changes in blood pressure included a more pronounced decrease in diastolic than preflight and an increase in mean dynamic and end systolic blood pressure in a number of instances. By the end of the flight, blood pressure response to the exercise test was approaching preflight levels. The data suggest some increase in the magnitude of response to graded physical exercise. However, tolerance of the test remained good. There were some inflight changes in the nature of the adaptive response to exercise: more marked decrease in peripheral resistance, leading to increased vascular capacitance; and increased cardiac ejection energy.

**LBNP test.** Inflight, both cosmonauts responded to this test with greater than baseline increases in heart rate, more pronounced in C-2. In C-1, end systolic pressure decreased more than preflight. In two tests, C-2 displayed change in the nature of his response, as manifest in more pronounced (compared to baseline) decrease in pulse pressure or increase in diastolic pressure accompanied by increased heart rate.

Postflight orthostatic tolerance was diminished postflight in both cosmonauts. C-1's tolerance was rated only satisfactory on days 1 and 2 postflight and good on day 4. C-2's tolerance was rated diminished on days 1 and 2 and fully satisfactory on day 4 postflight. A tilt test performed on days 5-7 postflight revealed satisfactory tolerance in both crewmembers. On day 16, tolerance was rated good (although below baseline) for one crewmember, and only satisfactory for the other.

**EVA studies.** Three EVAs were performed on this flight, on days 64, 192, and 304. Total energy expended was 890-1250 calories for C-1 and 920-1320 calories for C-2, with mean expenditure per minute of 3.4-3.9 and 3.4-4.0, respectively. Heart rate fluctuated between 68-122 and 72-128 beats per minute and temperature behind the ear was 35.9-37°C and

## SPACE BIOLOGY AND MEDICINE

34.5-36.5°C, for C-1 and C-2, respectively. No significant deviations from normal health status were noted during EVAs, with the exception of severe fatigue of arm muscles during the second EVA, associated with holding the body in place at the work site. Use of additional restraints during the third EVA diminished this symptom.

**Motor studies.** Study of the afferent component of the motor system on days 4-5 postflight failed to reveal significant changes. Threshold of vibration sensitivity of the plantar surface of the foot was within the limits of preflight values. The threshold of the Achilles reflex was also close to baseline, but the amplitude of the reflex exceeded preflight by a factor of 3, continuing to be above baseline on days 7-9.

Isokinetic dynamometry on day 8 postflight failed to reveal pronounced hypotrophy of the antigravity musculature. The strength characteristics of the triceps of the calf were 16% and 36% above preflight in the strength and isometric modes for C-1 and C-2, respectively. The exception was the speed mode (180°/second), in which strength properties were markedly diminished in both subjects. The tibialis anterior muscle suffered more, with strength loss in all testing modes ranging from 23 to 59%. Work capacity of the calf muscles was diminished by more than a factor of 4 in both cosmonauts.

Although motor coordination was found to be impaired postflight, changes were less severe than during long-term flights of shorter duration. Stabilography revealed that vertical (postural) stability was no different from baseline, with the exception of a slight increase in the range of fluctuations in overall center of gravity and the level of tremor. More pronounced changes occurred in response to forces pushing the body off balance (decrease in threshold of postural corrective responses to disruption, increased time to recover postural balance and electromyographic cost of vertical posture). Although these changes suggest some coordination impairment, they were not great.

Dysmetria was noted in both cosmonauts. Accuracy on a graded effort test diminished to 40% from a baseline of 100%. A test of rapid gaze fixation revealed increase of errors from 3-5% to 50%, and from 15-18% to 75% in the presence of optokinetic stimulation. On day 14 postflight, deviations had decreased but accuracy remained substantially diminished.

The flight induced profound changes in parameters of the gaze fixation response, reflecting behavioral and neural reflexive adaptation in control of eye-head coordination. On day 4 postflight both cosmonauts displayed inhibition of head movements and thus increase in contribution of saccadic movements to the response (behavioral adaptation). At the same time the gain of the vestibulo-oculomotor reflex underwent substantial changes in opposite directions in the two cosmonauts.

Thus, a 1-year flight led to the development of changes in various components of the motor system in both crewmembers. These changes are characteristic of response to microgravity and the majority were not great. Greatest deviations postflight occurred in the system responsible for motor control and these persisted in diminished form for more than 2 weeks postflight.

**Status of function of the vestibular and associated sensory systems.** Studies performed on day 1 postflight revealed enhanced vestibular reactivity and increased eye movements in C-1, with end-position nystagmus. Signs of vestibular dysfunction were more severe in C-2. On day 1, he displayed negative otolith reflexes in all postures. Low-amplitude low frequency clonic nystagmus occurred in vertical and horizontal leads, intensifying when his eyes were open. Shaking of the head evoked significant sensory and vestibular reactions. Repeat studies of both cosmonauts on days 5 and 15 revealed marked improvements.

## SPACE BIOLOGY AND MEDICINE

**Bone tissue.** Postflight studies of bone tissue using qualitative computer tomography revealed decreased mineral density of spongy bone of the Lumbar vertebrae in C-2. As occurred after a 150-day flight, severity of these changes diminished from L1 to L3 and amounted to 8, 10, and 12%. Dual photon absorptiometry in C-2 revealed a slight increase in mineral density of the bones studied.

**Metabolic studies.** Studies performed on day 7 identified metabolic changes, which were generally in the same direction in both cosmonauts. With respect to protein-nitrogen metabolism both subjects displayed decrease of  $\alpha$ - and  $\gamma$ -globulin fractions of protein, accompanied by increase in atherogenic  $\beta$ -globulins, suggesting decreased biosynthetic activity of the liver. Blood creatinine and uric acid had not normalized by day 7. C-1 displayed a slight increase in total protein and albumins in blood, and C-2 displayed a decrease in protein level with a slight increase in albumins and urea. With respect to carbohydrate metabolism, levels of glucose and lactate in blood were elevated to the point of moderate hyperglycemia on day 1 postflight. C-1 also displayed elevated pyruvate. Glucose level normalized by day 7. Inflight (days 321 and 332) and postflight (day 15) studies revealed changes in the nature of the glucose tolerance curve. In C-1 on day 321, the curve was flattened without noticeable increase in glucose after loading. On day 332 there was a tendency to normalize, but the increase in level did not reach baseline, and utilization of excess glucose was retarded (from 60 to 120 minutes). In C-2 the glycemic curve was analogous to preflight on day 321, but on day 332 it was depressed and bimodal in shape. On day 15 postflight, blood glucose was somewhat higher than preflight 30 minutes after loading in C-1 and at preflight level for C-2. With respect to lipid metabolism, it was found that triglycerides tended to be depressed and free fatty acids elevated on day 1 postflight. On day 7 postflight, triglycerides had normalized while free fatty acids remained elevated. Plasma level of linoleic acid decreased and level of arachidonic acid increased. Level of arachidonic acid in lipid membranes of erythrocytes was elevated on day 1 and normal on day 7.

**Studies of serum enzymes** performed on day 1 postflight revealed a decrease in activity of isocitrate dehydrogenase, and in overall activity of malate dehydrogenase and its mitochondrial isoenzyme. These decreases were more severe than after other long-term flights. There was also a decrease in lactate dehydrogenase. Activity of creatinine phosphokinase was elevated postflight due to its muscle isoenzyme, as was noted after previous long-term flights. Activity of alkaline phosphatase was considerably elevated postflight, which is attributed to increased function of bone cells. Activity of acid phosphatase was also elevated in C-1, while activity of aspartate transaminase was depressed in both crewmembers. The majority of deviations had normalized by day 7 postflight.

**Erythrocyte metabolism** was studied on day 7 postflight. C-1 displayed a tendency for metabolic processes in erythrocytes to be activated. At the same time, C-2 displayed a significant decrease in level of ATP and reduced glutathione and increased rate of glycolysis, which may be a result of increased uptake of this nucleotide due to changes in activity of membrane processes. This is confirmed by the fact that the same cosmonaut displayed changes in activity of Na, K-ATPase, and Ca-ATPase, decreased cell deformability and increased cell resistance to acid hemolysis. On day 70 postflight, erythrocyte metabolism corresponded to the physiological norm. However, Na and K-ATP activity was depressed in both subjects. In C-2 cell resistance was also diminished. Erythrocyte levels of potassium and sodium were unchanged at all points, indicating lack of significant disruption of membrane permeability.

On day 0 postflight fluid balance was little different from baseline in either cosmonaut. On day 1 postflight fluid was retained and renal excretion of osmotically active substances and sodium was diminished. Bivalent ion excretion was at preflight level. Ionized calcium was elevated in blood of both crewmembers and that of potassium was depressed in C-1. All changes, with the exception of ionized calcium in C-1, had normalized by day 7 postflight. A calcium loading test

## SPACE BIOLOGY AND MEDICINE

performed on day 42 postflight revealed elevated excretion in C-1 (compared to baseline) and diminished excretion in C-2. Changes were no more pronounced than after other long-term flights of lesser duration.

**Endocrine system.** Tests performed on days 1 and 7 postflight identified a number of changes in endocrine function. Within the pituitary-adrenal system, plasma concentration of ACTH had increased more than 10-fold on day 1, while only insignificant changes occurred in levels of hydrocortisone, possibly reflecting decreased sensitivity of the adrenal cortex to ACTH. On day 7 ACTH had diminished somewhat, but even on day 70 it had not returned to baseline. On day 1 postflight, concentration of TSH was somewhat depressed in blood. Within the sympathetic adrenal system (SAS), on the day of landing excretion of epinephrine was elevated while excretion of norepinephrine, dopamine, normetanephrine, vanilylmandelic acid, and homovanillic acid was diminished. On day 1 postflight, blood epinephrine and norepinephrine were elevated. These changes persisted on day 7. As had occurred after other flights, levels of E prostaglandins were markedly depressed in both crewmembers, persisting until day 70 postflight. Levels of group F<sub>2α</sub> prostaglandins were elevated on day 1, but sharply decreased on day 70. Despite increased activity of SAS, cyclic nucleotides in blood plasma were not significantly different from preflight levels, indirectly suggesting decrease of activity and/or number of adrenergic receptors. On day 1 postflight, investigation of hormones regulating fluid-electrolyte metabolism revealed increase in blood ADH (by a factor of 2-20), without changes in activity of renin or aldosterone concentration. However, on day 7, aldosterone was elevated. These changes suggest that recovery of fluid loss is faster than that of sodium. On days 1-7, C-1 displayed increased blood insulin. Concentration of growth hormone was below measurable limits for both cosmonauts. Calcitropic hormone was unaltered in C-1 and depressed in C-2 (persisting until day 70). In C-2 parathyroid hormone was also elevated on days 1-7 postflight.

Cholinergic enzymes inactivating acetylcholine fluctuated within relatively narrow limits in both cosmonauts postflight. Activity of the histaminergic and serotonergic systems increased postflight. Activation of the serotonergic system may be considered a compensatory reaction, while activation of the histaminergic system suggests possible allergic responses.

**Blood system.** Clinical analysis of blood performed during the last half of the flight showed that a number of hematological parameters (numbers of erythrocytes, reticulocytes, and other blood cells) remained within normal limits. Once C-1 displayed eosinophilia, and C-2 manifested a single instance of slight leukoneutropenia. Postflight both C-1 and C-2 displayed decrease in number of reticulocytes (by 69.3 and 43.1%, respectively), number of erythrocytes (by 170 and 540 thousand) and hemoglobin weight (by 11 and 12.2%, respectively), and also anisocytosis. By day 7 postflight, with recovery from hypohydration, there was a further decrease in red blood parameters and a 6-8% decrease in hematocrit. Reticulocytopenia was gradually replaced with an increasing reticulocytosis.

**Immune system.** Changes in the immune system after the 1-year flight included moderate decrease in PHA-activity of T-lymphocytes (decrease in level of cells with a high rate of RNA synthesis from 23.2-25.2% preflight to 12.8-14.0% postflight, with the lower boundary of the norm, equal to 15%); suppression of T-lymphocyte proliferation in PHA cultures (by a factor of 1.9-3.2); and decrease in production by lymphocytes of interleukin-2, supporting growth of T-lymphocytes and increased antibody genesis. Parameters of antiviral resistance remained at a high level. All changes normalized within a week. However, in one cosmonaut 2 months postflight, quantity of T-helpers activating the immune response remained depressed.

The authors conclude that the results obtained during and after the 1-year flight attest to the cosmonauts' maintenance of good health and adequate performance. After the flight, the

## SPACE BIOLOGY AND MEDICINE

cosmonauts tolerated renewed exposure to gravity in a satisfactory manner. The course of readaptation was favorable and did not differ from that after shorter long-term flights. No qualitatively new changes were found in any of the systems studied. Changes in a number of systems (motor, cardiovascular, bone, etc.) were actually less severe than after other long-term flights. At the present time the health of both cosmonauts meets criteria for fitness to fly in space again.



**MONOGRAPHS:**

M167(30/91) At'kov OYu, Bednenko VS.

Gipokineziya, nevesomost': Klinicheskiye i fiziologicheskiye aspekty; Гипокинезия; невесомость: Клинические и физиологические аспекты *Hypokinesia and Weightlessness: Clinical and Physiological Aspects.*

Moscow: Nauka; 1989.

[304 pages; 22 Tables; 28 Figures; 511 References]

Authors' Affiliations: At'kov, Head, Department of New Diagnosis and Research Methods, All-Union Cardiological Center, USSR Academy of Medicine; Bednenko, Director, Laboratory of Medical Monitoring and Research Methods; Institute of Biomedical Problems, USSR Ministry of Health.

**KEY WORDS:** Space Biology and Medicine, Hypokinesia, Long-Term, Weightlessness, Space Flight, Long-Term, Salyut-7, Mir, Adaptation, Cardiovascular and Respiratory Systems, Hemostasis, Prophylactic Countermeasures, Neurophysiology, Metabolism, Musculoskeletal System

Translation of Russian Annotation: This book is devoted to a timely problem — that of adaptive restructuring of physiological systems under conditions of hypokinesia and weightlessness. The authors use the results of their own unique research on Salyut-7 to define the characteristics of clinical evaluation of health status and the phases of restructuring of parameters of the cardiovascular system, visceral organs, and other systems. They present detailed discussion of the analogous symptoms of the adaptation syndrome in cosmonauts in weightlessness during flights of the Salyut and Mir stations and during the period of readaptation. The book is intended for physicians, physiologists, and designers of medical equipment.

Edited Version of English Annotation: This monograph summarizes the results of over 10 years of experimental, clinical, and physiological research. The authors analyze in detail their own results as well as data in the literature dealing with the multiple physiological effects of hypokinesia and weightlessness. They present and discuss a hypothesis that systemic hemostasis is supported at an appropriate level at the expense of increasing strain on the mechanisms responsible for regulation of regional hemodynamics, including that of the visceral organs. They discuss the characteristics of the adaptation syndrome in cosmonauts during long-term flight on the Salyut and Mir stations as well as during the postflight readaptation period. The monograph analyzes the comparative efficiency of various prophylactic countermeasures, including some developed by the authors. The data presented were obtained through the use of state-of-the-art (modeling) techniques, and from cosmonauts completing 237- and 326-day space flights, and subjects undergoing a 360-day period of hypokinesia. This monograph is intended for physicians, biologists, physiologists, and specialists in clinical and functional diagnosis, space biology, and medicine.

**CONTENTS**

Foreword (5)

List of Abbreviations (7)

## SPACE BIOLOGY AND MEDICINE

### Chapter 1. Adaptive restructuring of physiological systems in weightlessness and hypokinesia (9)

- 1.1 Changes in the major physiological functions in weightlessness and hypokinesia (9)
- 1.2 Nervous system (18)
- 1.3 Cardiovascular system (26)
- 1.4 Visceral organs (42)
  - 1.4.1 Liver (42)
- 1.5 Musculoskeletal system (42)
- 1.6 Hemodynamic reactions to provocative loading tests and environmental factors during their readaptation period (72)

### Chapter 2. Hypokinesia and the state of the physiological systems in humans (78)

- 2.1 Short-term hypokinesia with head-down tilt and immersion in water (78)
  - 2.1.1 The design and methodology of research (78)
  - 2.1.2 6-8 hour hypokinesia with head-down tilt (82)
  - 2.1.3 Combined effects of hypokinesia with head-down tilt ( $-10^{\circ}$ ) and lower body negative pressure (LBNP) (93)
  - 2.1.4 Combined effects of hypokinesia with head-down tilt and vestibular and optokinetic stimulation over a period of 6-8 hours (99)
  - 2.1.5 Combined effects of hypokinesia with head-down tilt, coriolis acceleration, optokinetic stimulation, and LBNP over a period of 6-8 hours (100)
  - 2.1.6 24-hour hypokinesia with head-down tilt ( $-15^{\circ}$ ) (101)
  - 2.1.7. A 3-hour period of immersion in water (102)
  - 2.1.8 A 7-day period of hypokinesia with head-down tilt ( $-10^{\circ}$ ) (104)
  - 2.19. Analysis of the characteristics of adaptive restructuring of the physiological systems and its genesis (105)
  - Conclusions (121)
- 2.2. Long-term hypokinesia with head-down tilt (122)
  - 2.2.1 Design and methodology of research (122)
  - 2.2.2 50-day period of hypokinesia with head-down tilt ( $-6^{\circ}$ ) (122)
  - 2.2.3 120-day period of hypokinesia with head-down tilt ( $-4.5^{\circ}$ ) (124)
  - 2.2.4 360-day period of hypokinesia with head-down tilt ( $-6^{\circ}$ ) (125)
  - 2.2.5 Dominant tendencies (141)
  - 2.2.6 Analysis of genesis of changes in the state of physiological system in long-term hypokinesia (143)
  - Conclusions (154)

### Chapter 3. The status of physiological systems in cosmonauts in flight and during the readaptation period (155)

- 3.1 Rate and volume changes of blood flow in the major vasculature of the head and lower limbs (156)
  - 3.1.1 Common carotid arteries (156)
  - 3.1.2 Internal jugular veins (168)
  - 3.1.3 Spinal arteries (176)
  - 3.1.4 Supratrochlear arteries (178)
  - 3.1.5 Femoral and posterior tibial arteries (183)
  - 3.1.6 Femoral veins (184)
- 3.2 State of the cardiac chambers and central hemodynamics (185)
  - 3.2.1 During flight (185)
  - 3.2.2 During readaptation (187)

## SPACE BIOLOGY AND MEDICINE

- 3.3. Dynamics of changes in the dimensions and volume of visceral organs (189)
  - 3.3.1 Liver (189)
  - 3.3.2 Spleen (195)
  - 3.3.3 Kidneys (198)
  - 3.3.4 Changes in amount of blood and body fluids in pulmonary tissue (204)
  - 3.3.5 Prostate gland (204)
- 3.4 Adaptive responses to provocative tests and use of countermeasures to prevent the adverse effects of weightlessness (204)
  - 3.4.1 Exercise (204)
  - 3.4.2 LBNP (212)
  - 3.4.3 Tilt tests (215)
  - 3.4.4 Excess pressure in the area of the thigh (218)
  - 3.4.5 Pharmacological tests (administration of nitroglycerine) (222)
  - 3.4.6 Combined use of drugs and physical devices to limit venous return to the heart (223)

### Chapter 4. Hypokinesia and weightlessness: Problems of pathogenesis, adaptation, correction and prevention of physiological effects (229)

- 4.1 General patterns in the development of the adaptation syndrome (229)
- 4.2 Clinical aspects of the effects of weightlessness and hypokinesia (238)
- 4.3 Prevention and corrections of changes (248)
- 4.4 Prediction of adaptation and postflight prophylactic measures (260)
- 4.5 Prospects for improving the systems for medical monitoring, diagnosis, and research (267)

Conclusion (274)

References (276)

M170(30/91) Gazenko OG, Kas'yan NI (Editors)

Fiziologicheskiye problemy nevesomosti; Физиологические проблемы невесомости

[*Physiological Problems of Weightlessness.*]

Moscow: Meditsina; 1990.

[288 pages; 21 Figures; 27 Tables; 127 references; 25 in English]

**KEY WORDS:** Space Biology and Medicine, Space Flight, Short-Term, Long-Term, Salyut-6, Salyut-7, Cardiovascular and Respiratory Systems, Neurophysiology, Space Motion Sickness, Body Fluids, Fluid Electrolyte Metabolism, Hypokinesia, Prophylactic Countermeasures, Human Performance, Operational Medicine, Cosmonauts

**Annotation:** This monograph considers the major achievements in Soviet space medicine during the 25-year history of manned flights and presents new experimental material. It compares the results of physiological research performed during cosmonaut flights on the Salyut-6 and -7 space stations. It considers parameters of hemodynamics, cardiac cycle phase structure, and especially cerebral and peripheral circulation at rest and during performance of provocative tests. It presents for the first time the results of a study of oxygen conditions in the tissues of cosmonauts. Data on pathogenesis of space motion sickness are cited. New data from biochemical and hematological studies and on the status of fluid-electrolyte homeostasis in hypokinesia and weightlessness are described. The issues of prophylactic maintenance of the health of cosmonauts on long-term flights are discussed. This monograph is intended for biologists and other scientists working in the area of space medicine.

Contents

**Foreword.** O.G. Gazenko

**Section I. Biomedical problems of weightlessness (5)**

Major achievements of Soviet space medicine during the 25-year history of manned space flights. O.G. Gazenko (5)

Human physiological response to space flight. O.G. Gazenko, A.I. Grigor'yev, A.D. Yegorov (15)

**Section II. The effect of weightlessness on the functional status of cardiovascular, respiratory, and other physiological systems in humans (49)**

Ultrasound studies of the cardiovascular system of cosmonauts. O.,Yu. At'kov, V.S. Bednenko, G.A. Fomina, V.V. Bystrov, Ye.P. Milova (49)

Research on the functional status of the cardiovascular system on long-term space flights. A.D. Yegorov, O.G. Itsekhovskiy, I.V. Alferova, A.P. Polyakova, I.I. Kas'yan, M.V. Doracheva, V.D. Turbasov, Z.A. Golubchikova, V.R. Lyamin, T.V. Batenkchuk-Tusko, Ye.A. Kobsev, A.P. Kulev. (70)

Characteristics of central and regional circulation on short-term and long-term space flights. V.G. Turchaninova, M.V. Domracheva, I.I. Kas'yan, Ye.P. Milova, I.F. Sarayev, V.A. Minenko (93)

Fluid-electrolyte homeostasis and its regulation. A.I. Grigor'yev, B.R. Dorokhova, V.B. Noskov, B.V. Morukov (123)

External respiration, gas exchange and energy expenditure of humans in weightlessness. I.I. Kas'yan, G.F. Makarov (136)

## **SPACE BIOLOGY AND MEDICINE**

Anthropometric studies in weightlessness. I.I. Kas'yan, V.A. Talavrinov, AA.D. Yegorov, V.I. Lukyanchikov (152)

### **Section III. Human performance in weightlessness (164)**

Cosmonaut work-rest schedules on long-term flights. V.I. Makarov (164)

Medical support of cosmonauts during EVAs. A.S. Barer, M.I. Vakar, S.N. Filipenkov, V.V. Shchigolev, Ye.A. Kovalenko, I.I. Kasyan, V.P. Zinchenko, L.G. Glovkin, Yu.Yu. Osipov (179)

### **Section IV. Pathogenesis and certain issues in preventing the effects of weightlessness (198)**

Space sickness. G.I. Gorgiladze, I.I. Bryanov, Ye.M. Yuganov. (198)

On the problem of pathogenesis of weightlessness effects. Ye.A. Kovalenko, I.I. Kas'yan (215)

The use of LBNP conditioning of cosmonauts on space station Salyut-7. V.M. Mikhaylov, Yu.D. Pometov, I.G. Ishcheskhovskiy (251)

### **Section V. Experimental studies (257)**

Study of the acute period of adaptation in primates. Ye.A. Il'in, V.I. Korol'kov, I.B. Kozlovskaya, V.P. Krotov, M.G. Sirota (257)

Addenda (277)

References (282)

## KEY WORD INDEX

Acceleration 10, 27, 80  
**Adaptation** 1-2, 14, 42, 63, 69, 96  
Adrenergic Regulation 14  
Age Differences 1  
Air Traffic Controllers 13, 26  
Aircraft Maintenance Teams 19  
Airtight Environments 2  
Alcohol Intoxication 80  
Arctic Conditions 2  
Ascorbic Acid 25  
Auditory Function 68  
Automicroflora 88  
Aviation Medicine 13  
Balkanin Substrate 35  
Behavior 59, 87  
Bioelectrical Cardiac Activity 6  
Biological Damage 20  
Biological Rhythms 13  
**Biospheric Research** 4  
Birds 37  
Blood Parameters 47  
Blood Plasma 25  
Blood Pressure Measurement 10  
Blood Profile 22  
Blood Proteins 25  
Blood Redistribution 10  
Body Fluids 46, 88, 99  
Bone Marrow 22  
Bone Tissue 88  
Bones 31, 47, 56  
Botany 35, 37  
Brain Status 80  
Burns 2  
Calcium Metabolism 31  
Carbohydrate Metabolism 88  
**Cardiovascular and Respiratory Systems** 4, 6-12, 88, 96, 99  
Catabolism 44  
Cats 67  
CELSS 35, 37  
Cholinergic Regulation 14  
Combined Effects 80, 82  
Compatibility 19  
Conditioned Responses 59  
Cosmonaut Diet 88  
Cosmonauts 6, 7, 8, 17, 28, 30, 31, 42, 44, 63, 68, 71, 76, 84, 88, 99  
COSMOS-1887 22, 53, 56  
COSMOS-2044 47, 59  
Cyclic Nucleotides 14  
Developmental Biology 37  
Diaphragm 53  
Dogs 80  
Dosimetry 84  
Doza-B 84

## KEY WORD INDEX

Echocardiography 12  
Electrical Activity 67  
Electron Paramagnetic Resonance 25  
**Endocrinology** 2, 13-14, 88  
Environmental Microflora 20  
**Equipment and Instrumentation** 16, 84  
Erythrocyte Metabolism 88  
Experimental Design 41  
Eye Movements 16, 63  
Eyes 87  
Females 77  
Flight Rations 76  
Fluid Electrolyte Metabolism 88, 99  
Frostbite 2  
GABA 25  
Gastrocnemius Muscle 48, 53  
**Gastrointestinal System** 17  
Geomagnetic Fields 4  
Graded Exercise Tests 44  
Group Dynamics 19  
**Habitability and Environment Effects** 20, 88  
Head Movements 63  
Healing Rate 47  
Heliobiology 4  
Hematocrit 24  
**Hematology** 22-25, 46, 88  
Hemostasis 96  
Higher Nervous Activity 59  
Horizontal Immersion 69  
**Human Performance** 13, 26-27, 99  
Humans 1, 6, 7, 8, 9, 10, 13, 14, 16, 17, 19, 24, 26, 27, 28, 30, 31, 42, 44, 46, 63, 69, 71, 76, 84, 88  
Humus 35  
Hyperoxia 80  
Hypokinesia 96, 99  
Hypokinesia With Head-Down Tilt 1, 10, 12, 28, 31, 42, 44  
370-Day 14, 24, 28, 31, 42  
Hypoxia 80  
Immersion 44  
Immune Status 31  
Immunodeficiency 2  
**Immunology** 2, 28-31, 88  
Impact 27  
Impedance Plethysmography 7  
Individual Differences 27, 77  
Information Deficit 78  
Information Interaction 26  
Injury 2  
Interleukin-2 30  
Intersensory Interaction 69  
Ionizing Radiation 80, 82  
Isolation 2  
LBNP 88  
LBNP Test 10

Leadership 19  
 Lettuce 35, 37  
**Life Support Systems 35-37**  
 Light Flashes 26  
 Lipid Metabolism 88  
 Lipid Peroxidation 25, 42  
 Long-Term Habitation 20  
 Lumbar Vertebrae 56  
 Lymphocytes 28, 30  
 Magnetic Field 82  
 Males 1, 9, 14, 19, 25, 27, 31, 44, 48, 67, 77  
 Man-Computer System 26  
 Mars Mission 85, 86  
 Mathematical Modeling 41, 78  
 Medial Vestibular Nucleus 67  
**Metabolism 25, 31, 42-46, 88, 96**  
 Mice 25  
 Microbiology 88  
 Microwave Radiation 80  
 Microwaves 82  
 Mir 6, 7, 8, 17, 30, 31, 37, 42, 68, 84, 88, 96  
 Monkeys 12, 59  
 Monoclonal Antibodies 28  
 Motor Control 88  
 Mountain Climbers 77  
 Muscle Fibers 48  
 Muscle Strength 88  
**Musculoskeletal System 31, 47-56, 88, 96**  
 Myocardium 12  
 Natural and Synthetic Materials 20  
 Neurodynamics 78  
 Neuromediators 67  
 Neuromodulators 67  
 Neuromuscle Synapses 53  
**Neurophysiology 4, 16, 53, 59-71, 78, 80, 88, 96, 99**  
 Noise 26  
 Number of Measurements 41  
**Nutrition 76, 88**  
 Operational Medicine 99  
 Optokinetic Stimulation 63  
 Organs 17  
 Penaz Method 10  
 Perception 68, 69, 71  
 Performance 9  
 Personality Traits 19  
 Photoelectric 16  
 Physical Exercise 9, 48, 88  
 Plants 35  
 Prime Crews 7  
 Problem Solving 26  
 Prophylactic Countermeasures 31, 88, 96, 99  
 Protein-Nitrogen Metabolism 88  
**Psychology 2, 13, 19, 26, 59, 76-78, 87,88**  
 Pumping Function 12



## KEY WORD INDEX

Quail 37  
Radiation 87  
Radiation Conditions 88  
Radiation Safety 82, 85, 86  
**Radiobiology** 4, 46, **80-87**, 88  
Radiobiology. Radiation Safety 82  
Radishes 37  
Rats 22, 47, 53, 56, 80, 82, 87  
Readaptation 1  
Recognition 78  
Regional Circulation 7  
Repeated Exposure 1  
Resistance 2  
Resistance to Respiration 9  
Rhesus Macaques 12, 59  
Risk Taking Behavior 77  
Rotational 16  
Rotational Acceleration 25  
Salyut-6 68, 99  
Salyut-7 31, 68, 96, 99  
Sensory Interactions 63, 71  
Sensory Physiology 69, 87  
Shift Work 13  
Short-Term 28, 30, 44, 99  
Skeletal Muscles 48  
Solar Effects 4  
Soleus 53  
Soviet-French Crew 8  
Space Adaptation Syndrome 69, 88, 99  
**Space Biology and Medicine** 41, **88-99**  
Space Flight 6, 7, 8, 14, 17, 22, 24, 28, 30, 31, 37, 42, 44, 47, 53, 56, 59, 63, 71, 76, 82, 84, 85, 86, 88, 96, 99  
    Long-Term 6, 7, 14, 24, 28, 30, 31, 44, 76, 96, 99  
    One-year 42, 88  
Space Greenhouses 35, 37  
Space Motion Sickness 69, 88, 99  
Spacecraft Cabins 20  
Statistical Reliability 41  
Stress 2, 13, 27  
Striated Muscle 53  
Structural Materials 20  
Substrate 35  
Sympathetic Adrenal System 13  
Tail Suspension 47  
Theoretical Article 85, 86  
Thermoluminescent Dosimeter 84  
Thymus 2  
Tibia 56  
Tilt Test 10  
Tracking Performance 27  
Ultraviolet 87  
Ultraviolet Irradiation 46  
Vestibuloautonomic Symptoms 69  
Vestibulomotor Reactions 63

## KEY WORD INDEX

Vibration 80  
Visual Field Inversion 69  
Visual Tracking 71  
Vitamin Fortification 76  
Work-Rest Schedule 88  
Zeolite 35

# Report Documentation Page

1. Report No. NASA CR-3922(36)		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle  USSR Space Life Sciences Digest - Issue 30				5. Report Date  May 1991	
				6. Performing Organization Code	
7. Author(s)  Lydia Razran Stone, Ronald Teeter, and Joseph Rowe*, Editors				8. Performing Organization Report No.	
				10. Work Unit No.  NASW-4292	
9. Performing Organization Name and Address Lockheed Engineering and Sciences Company 600 Maryland Avenue, SW, Suite 600 Washington, D.C. 20546-0001				11. Contract or Grant No.	
				13. Type of Report and Period Covered  Contractor Report	
12. Sponsoring Agency Name and Address  Office of Space Sciences and Applications National Aeronautics and Space Administration Washington, DC 20546-0001				14. Sponsoring Agency Code	
15. Supplementary Notes  *Library of Congress, Washington, DC					
16. Abstract  This is the thirtieth of NASA's USSR Space Life Sciences Digest. It contains abstracts of 47 journal or conference papers (including all papers in Issue 5, 1990 of the journal "Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina") published in Russian and of six Soviet monographs. Selected abstracts are illustrated with figures and tables from the original. An article describing the hatching of quails in space is translated in full. The materials in this issue have been identified as relevant to 20 areas of space biology and medicine. These areas are: adaptation, biospheric research, cardiovascular and respiratory systems, endocrinology, equipment and instrumentation, gastrointestinal system, group dynamics, habitability and environment effects, hematology, human performance, immunology, life support systems, mathematical modeling, metabolism, musculoskeletal system, neurophysiology, nutrition, psychology, radiobiology, and space biology and medicine.					
17. Key Words (Suggested by Author(s)) space biology, aerospace medicine, flight experiments, flight simulation, microgravity, USSR			18. Distribution Statement  Unclassified - Unlimited  Subject Category 51		
19. Security Classif. (of this report)  Unclassified	20. Security Classif. (of this page)  Unclassified		21. No. of pages  110	22. Price  A06	

